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AERODYNAMIC DESIGN AND ANALYSIS OF THE AST-200
SUPERSONIC TRANSPORT CONFIGURATION CONCEPT

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SUMMARY

The design and analysis of a supersonic transport configuration has been conducted using linear theory methods in conjunction with appropriate constraints. A configuration which was developed through previous systems studies has been used as the baseline for the present design and analysis. Wing optimization centered on the determination of the required twist and camber and proper integration of the wing and fuselage. Also included in the design are aerodynamic refinements to the baseline wing thickness distribution and nacelle shape. Analysis of the baseline and revised configurations indicated an improvement in lift-to-drag ratio of 0.36 at the Mach 2.7 cruise condition. Validation of the design is planned through supersonic wind tunnel tests.

INTRODUCTION

High-speed aerodynamic performance for NASA-Langley Research Center AST (Advanced Supersonic Technology) concepts of current interest is usually estimated from wind tunnel data obtained during the late 1960's for the NASA SCAT 15F configuration (refs. 1 and 2). The SCAT 15F was designed using the then available linear theory methods, and has demonstrated very high levels of aerodynamic performance at the Mach 2.7 cruise condition. Present AST concepts employ a highly-swept arrow wing similar to the SCAT 15F and are designed for the same Mach 2.7 cruise. As these AST concepts have continued to evolve, however, it has become necessary to apply increasingly larger corrections to the wind tunnel data to account for differences between the model and present study concepts. The availability of more recent wind tunnel data for the McDonnell-Douglas Mach 2.2 AST concept (ref. 3) has not alleviated this data base problem because of significant differences in configuration geometry and design Mach number relative to the NASA AST configurations.

The need to establish an updated experimental data base which is more consistent with current Mach 2.7 AST study concepts is apparent. The purpose of this report is to describe the aerodynamic design of the AST-200 configuration which is typical of concepts currently under study at NASA-Langley.

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The development of the AST-200 is centered on determination of the optimum wing twist and camber distribution using linear theory methods which have been significantly expanded and improved since the SCAT 15F design. Other aerodynamic refinements have been identified through various systems studies and are also included. Wind tunnel tests of this updated configuration are planned to validate the design and provide the required data base for future configuration studies.

SYMBOLS

A	fuselage cross-sectional area
$A_1, A_2, \ldots A_9$	coefficients for the component wing loadings
b	wing span
c	wing local chord
$\bar{c}$	wing mean aerodynamic chord
C_D	drag coefficient, $\dfrac{\text{drag}}{qS}$
C_{D_i}	drag-due-to-lift coefficient, $\dfrac{\text{drag-due-to-lift}}{qS}$
CG	center-of-gravity
C_L	lift coefficient, $\dfrac{\text{lift}}{qS}$
C_m	pitching moment coefficient, $\dfrac{\text{pitching moment}}{qS\bar{c}}$
C_{m_0}	pitching moment at zero lift
C_p	pressure coefficient, $\dfrac{P-P_\infty}{q}$
$C_{p_{vac}}$	vacuum pressure coefficient, $\dfrac{-P_\infty}{q}$
C_R	wing root chord (at $y = 0$)

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i_T	horizontal tail incidence, degrees
k_E	drag-due-to-lift factor
L/D	lift-to-drag ratio
M_∞	freestream Mach number
P	static pressure
P_∞	freestream static pressure
q	freestream dynamic pressure
S	reference wing area
$t/2c$	wing half-thickness, percent
X, Y, Z	configuration longitudinal, spanwise, and vertical coordinates
Z_c	camber coordinate
α_{TWIST}	wing section twist angle relative to the horizontal wing reference plane
α_{WRP}	angle of attack of the wing reference plane

DESIGN CONSIDERATIONS

The intent of the present design effort was to define an AST configuration sufficiently typical of concepts currently under study at the NASA-Langley Research Center that planned wind tunnel tests of the design will provide a readily applicable data base for future configuration studies. Improved cruise performance was achieved through application of refined lienar theory design methods and incorporation of additional aerodynamic improvements. Results from previous systems studies (e.g., ref. 4) were used as a guide in applying the linear theory and other aerodynamic improvements. The resulting config-uration thus represents a viable concept which meets volume and structural requirements defined through detailed systems studies.

The design of the AST-200 has proceeded from a baseline definition which was developed from previous system studies. Aerodynamic improvements to the baseline wing thickness distribution and nacelle shape were incorporated and an optimum twist and camber distribution was developed. The wing and fuselage were carefully integrated and the fuselage area-ruled for minimum wave drag at the Mach 2.7 cruise condition.

Design conditions and constraints employed in the wing twist and camber optimization included a design lift coefficient of C_L = 0.10 at Mach 2.7 with the wing self-trimming for a center-of-gravity (CG) location of $0.49\bar{c}$. Wing upper surface pressure coefficients were constrained to be no more negative than $0.7\ C_{p_{VAC}}$ with gradients less than 0.164 per meter (0.0050 per foot). The wing centerline twist was constrained to maintain an acceptable cabin floor angle.

Aerodynamic design and analysis for the AST-200 is presented below for the full scale configuration.

BASELINE CONFIGURATION DESCRIPTION

The configuration selected as the baseline for this design effort is designated the AST-102 (fig. 1). This configuration is a resized version of the AST-100 described in reference 4 and is a conventional fossil-fueled supersonic cruise transport concept. The AST-102 configuration incorporates a highly swept arrow wing designed for cruise at a Mach number of 2.7. The wing gross area is 866 m^2 (9317 ft^2) and the associated reference area is 785 m^2 (8447 ft^2). Wing twist and camber were developed from the SCAT 15F geometry (refs. 1 and 2), and the wing thickness distribution was designed to meet structural and volume requirements while simultaneously providing low wave drag characteristics. Five abreast seating is provided in the fuselage for 273 passengers. The fuselage is area ruled for optimum cruise performance. Four engine nacelles are located beneath the wing trailing edge in a conventional manner. Vertical wing fins and the vertical and horizontal tails were sized to meet trim, stability, and control criteria consistent with that for the AST-100 (ref. 4).

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A standard numerical model description (ref. 5) of the AST-102 is presented as table I. The wing size and planform, fuselage length, and wing fin and empennage geometry defined in this table apply directly to the AST-200. Other geometry revisions developed in the design process are discussed below.

AST-200 DESIGN

The baseline AST-102 configuration described above was redesigned by incorporating several aerodynamic refinements and using an improved linear theory method to optimize the wing twist and camber. This linear theory design and analysis methodology is presented in reference 6 and will be referred to as the Boeing program. Application of this linear theory and incorporation of the other aerodynamic improvements are discussed in the following sections.

Nacelle Revision

The AST-102 nacelle shape incorporated a relatively short conical forebody and a long cylindrical afterbody (fig. 2). Zero-lift wave drag studies using the far-field method (ref. 7) indicated that a wave drag decrease of 1.1 drag counts (.00011) could be achieved by modifying the nacelle geometry to that shown in figure 2 for the AST-200. At lifting conditions, an additional interference drag decrease of 0.8 counts was estimated using the Boeing program (ref. 6). A slight reduction in nacelle wetted area and skin friction also occurred resulting in a total drag decrease of 2.0 counts at the Mach 2.7 cruise condition. The revised nacelle shape resulted in improved cruise performance while providing sufficient volume to house the engine originally defined for the AST-102 baseline.

Wing Thickness Development

A wing thickness distribution which has improved wave drag performance relative to the AST-102 was developed from the NACA 64A series airfoil sections (ref. 8). These airfoil sections have traditionally provided good supersonic

performance for subsonic leading edge wings. The maximum thickness for airfoils of this series occurs at the 40 percent chord location, and some modifications are required to adapt these sections to AST configurations which typically require the maximum thickness to be located further aft for structural considerations.

Previous AST-102 configuration studies identified the required maximum thickness and location from wing volume and structural considerations. These same maximum thickness values and locations have been applied to the AST-200, but the basic thickness shape has been modified as follows: As shown in figure 3, a 64A series airfoil section having the required maximum thickness for a given spanwise location on the wing was defined using the data from reference 8. This initial section has its maximum thickness at the 40 percent chord location. The maximum thickness was held constant from this point to the most aft point of maximum thickness taken from the AST-102. A second 64A section was then defined which has a maximum thickness different from the first, but which passes through the most aft point of maximum thickness on the revised section. The resulting airfoil is thus composed of two NACA 64A airfoil sections with a "flat-top" region between them. Typical comparisons of the revised and baseline thickness envelopes are shown in figure 4. Note that the AST-200 sections have somewhat increased depth forward, but reduced depth aft of the rear maximum thickness point. Note also that the wing tip panel which has a supersonic leading edge has been modified to incorporate a circular arc airfoil section with the maximum thickness at the 50 percent chord point. The thickness has been increased to three percent to provide more depth in the tip panel for such items as flap actuators and lights. Figure 5 summarizes the spanwise variation of the maximum thickness location and magnitude.

The revisions to the wing thickness distribution resulted in a nine percent reduction in wing volume for the AST-200. This decrease occurs in the trailing-edge region of the wing where the flaps are located and thus does not penalize the fuel volume capability of the AST-200. The AST-200 wing thickness in the trailing-edge region should be sufficient to house the flap actuators without wing bumps. The increase in wing tip panel

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thickness resulted in a negligible increase in the far-field wave drag. A net wave drag reduction of 0.5 counts (.00005) was estimated for the wing using the method of reference 7.

Wing Twist and Camber Design

Determination of the optimum wing twist and camber subject to the design constraints previously noted was accomplished using the linear theory methods of reference 6. This methodology incorporates many improvements to the basic theory which have evolved since the SCAT 15F design. Reference 9 presents a discussion of the fundamental details of the computational methods employed in reference 6. The present methodology allows for direct application of various constraints and iterates for the required twist and camber solution.

The loading for determining the twist and camber is optimized from a predefined set of component loadings in conjunction with a series of configuration dependent loadings for fuselage upwash and bouyancy and nacelle bouyancy. Initial design solutions for the AST-200 wing alone indicated that inclusion of the uniform and linear spanwise component loadings produced unmanageable wing root camber. These results were very similar to those obtained in reference 10 for a supersonic cruise fighter wing. The solution to this problem adopted in reference 10 has also been applied to the AST-200 design. The basic component loadings defined in the Boeing program have been replaced with the series of apex loadings defined in reference 10. The configuration dependent loadings have been retained unaltered. Exclusion of the uniform and linear spanwise loadings when using these apex loadings resulted in a more satisfactory camber distribution solution.

Design of the wing in the presence of the fuselage requires modifications to the basic wing upper surface pressure constraints to account for the real flow effects of inboard shock separation. Reference 11 presents a detailed discussion of the inboard shock and provides a method for computing allowable pressure coefficients on the wing. Attempts to design the wing in the presence of the fuselage with these pressure constraints proved unsuccessful. Both unsatisfactory camber shapes and unrealistic drag levels were obtained

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in all cases. The fuselage was thus not considered in the wing camber design, but was carefully integrated with the final wing as discussed in a later section.

The effects of the nacelles were included directly in the design. As noted in reference 6, two nacelle loadings are available: (1) the nacelle bouyancy loading and (2) a camber-induced loading proportional to the nacelle bouyancy loading. The best overall design was obtained when only the nacelle bouyancy loading was used and the camber-induced loading was omitted. A Z-constraint was ultimately included at the wing root trailing edge to maintain an acceptable cabin floor angle.

Table II summarizes the AST-200 design constraints, loadings, and results. The corresponding camber and twist distributions are compared with the AST-102 baseline in figures 6 and 7, respectively.

The linear theory used in this design does not recognize out-of-plane wing shear and essentially provides a wing with the leading-edge lying in the horizontal reference plane. A shear distribution was developed for the AST-200 which maintains straight, but not necessarily horizontal, trailing-edge flap hinge lines. The AST-102 baseline was used as a guide to define wing anhedral/dihedral angles for the various wing segments. A comparison of the AST-102 baseline and the AST-200 wing leading and trailing edges is presented in figure 8.

Wing-Body Integration

As previously noted, the fuselage induced loadings were excluded from the wing camber surface optimization. The wing and fuselage have been carefully integrated, however, to maintain as closely as possible the optimum wing aerodynamic characteristics. The procedure utilized has been discussed in references 12 and 13 and requires that the change in cross-sectional area with length ($\partial A/\partial x$) above and below the wing camber surface be held equal for each fuselage station. The interactive computer code described in reference 13 was used to perform the integration process. The key station was defined such that a low wing configuration could be established.

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The resulting fuselage camber distribution is shown in figure 9. Note that the AST-200 has a circular fuselage.

Wave Drag Optimization

The AST-200 fuselage area distribution was optimized for minimum wave drag at Mach 2.7 subject to a five abreast seating area constraint using the method of reference 7. Figure 10 compares the AST-200 fuselage area distribution with the baseline.

The AST-200 Configuration

A numerical definition (ref. 5) of the AST-200 configuration is presented as table III. The data are for the full scale configuration. Note again that the wing fins and empennage are unchanged from those of AST-102 baseline.

AERODYNAMIC ANALYSIS

The AST-102 baseline and the AST-200 design have been analyzed at Mach numbers of 2.7 and 1.2 to determine the incremental improvements in the aerodynamic performance. The Boeing program (ref. 6) has been used to compute the skin friction and drag-due-to-lift characteristics whereas the method of reference 7 was employed for the wave drag analysis. The fuselage was included in the skin friction and wave drag analyses, but not in the drag-due-to-lift analysis. With the fuselage so excluded, the Boeing program computes the drag-due-to-lift characteristics of the wing-nacelles-horizontal tail combination. Both configurations were trimmed using the horizontal tail at lift coefficients of 0.10 and 0.15 at Mach numbers of 2.7 and 1.2, respectively.

The traditional discrepancies between the design and analysis methods (ref. 9) resulted in predicted aerodynamic characteristics which differ somewhat from the design results. In particular, note that although the AST-200 was designed to be self-trimming at cruise, the analysis results indicate that a small upload on the horizontal tail is required to trim. This small upload is favorable to the overall configuration performance

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as discussed in reference 14. The effect of the fuselage is to destabilize the configuration and require an additional small horizontal tail upload.

The computed aerodynamic characteristics are presented in figure 11. Of particular interest are the improvements in lift-to-drag ratio obtained by the AST-200 design. An increment of +0.36 in cruise lift-to-drag ratio is estimated.

CONCLUDING REMARKS

The AST-200 is a conventional, circular cross-section fuselage supersonic transort. The aerodynamic design of this configuration using linear theory methods has resulted in improved aerodynamic performance relative to a baseline predecessor.

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Table I. - AST-102 Numerical Model

(a) SI Units (meters)

AST-102 BASELINE FOR AST-200 DESIGN

```
 1  1 -1  1  1  1      12 28  1 19 30                      2  4  2 10  1 10

784.75
                                                                       REFA
0.      .125    .25     .5      .75     1.0     1.5     2.5     5.0     10.    XAF 10
15.     20.     25.     30.     35.     40.     45.     50.     55.     60.    XAF 20
65.     70.     75.     80.     85.     90.     95.     100.                   XAF 28
21.726   1.569  -1.551  45.864                                                WORG  1
22.862   1.894  -1.848  44.720                                                WORG  2
25.551   2.665  -2.314  42.015                                                WORG  2
29.470   3.789  -2.737  38.073                                                WORG  3
36.077   5.684  -3.214  31.427                                                WORG  4
38.761   6.453  -3.388  28.727                                                WORG  5
42.683   7.578  -3.627  25.112                                                WORG  6
48.154   9.146  -3.851  20.070                                                WORG  7
52.352  10.606  -3.986  16.271                                                WORG  8
54.543  11.367  -4.076  14.753                                                WORG  9
62.201  14.028  -4.359   9.446                                                WORG 10
71.380  19.328  -4.898   4.949                                                WORG 11
                                                                              WORG 13
0.000   .000    .000    0.000   -.000   -.001   -.002   -.007   -.037  -.146  TZ 1.1
-.312   -.514   -.742   -.971   -1.215  -1.459  -1.695  -1.947  -2.170 -2.393  TZ 1.2
-2.587  -2.769  -2.940  -3.097  -3.243  -3.375  -3.490  -3.591                 TZ 1.3
0.000   .000    .001    .001    .001    .001    .000    -.002   -.012  -.095   TZ 2.1
-.230   -.401   -.596   -.791   -1.010  -1.229  -1.453  -1.678  -1.877 -2.076  TZ 2.2
-2.253  -2.427  -2.592  -2.758  -2.904  -3.039  -3.151  -3.246                 TZ 2.3
0.000   .001    .002    .004    .005    .007    .010    .016    .025   .020    TZ 3.1
-.121   -.247   -.400   -.553   -.724   -.895   -1.072  -1.248  -1.418 -1.588  TZ 3.2
-1.742  -1.900  -2.051  -2.194  -2.329  -2.452  -2.564  -2.663                 TZ 3.3
0.000   .002    .003    .005    .009    .011    .016    .024    .040   .016    TZ 4.1
-.048   -.134   -.241   -.347   -.470   -.593   -.724   -.854   -.987  -1.119  TZ 4.2
-1.250  -1.379  -1.505  -1.626  -1.744  -1.857  -1.963  -2.063                 TZ 4.3
0.000   .002    .003    .006    .009    .013    .020    .031    .058   .069    TZ 5.1
.048    .009    -.048   -.105   -.176   -.249   -.330   -.412   -.499  -.586   TZ 5.2
-.675   -.764   -.854   -.944   -1.032  -1.118  -1.203  -1.286                 TZ 5.3
```

0.000	.002	.004	.008	.012	.016	.024	.040	.076	.097	TZ 6.1
.089	.062	.019	-.023	-.080	-.137	-.203	-.268	-.340	-.411	TZ 6.2
-.486	-.562	-.638	-.714	-.790	-.865	-.938	-1.013			TZ 6.3
0.000	.002	.003	.006	.009	.013	.020	.031	.061	.094	TZ 7.1
.097	.083	.058	.032	-.007	-.045	-.093	-.140	-.192	-.245	TZ 7.2
-.300	-.356	-.415	-.473	-.531	-.591	-.650	-.708			TZ 7.3
0.000	.001	.002	.005	.008	.010	.014	.023	.037	.063	TZ 8.1
.070	.063	.048	.034	.016	-.001	-.030	-.059	-.090	-.121	TZ 8.2
-.154	-.188	-.224	-.261	-.297	-.334	-.372	-.407			TZ 8.3
0.000	.001	.002	.003	.004	.005	.007	.011	.021	.037	TZ 9.1
.048	.051	.046	.042	.032	.021	.007	-.008	-.027	-.045	TZ 9.2
-.065	-.087	-.109	-.133	-.157	-.182	-.208	-.234			TZ 9.3
0.000	.001	.001	.002	.003	.004	.005	.009	.016	.027	TZ 10.1
.034	.037	.034	.032	.024	.017	.005	-.007	-.022	-.037	TZ 10.2
-.054	-.072	-.091	-.111	-.131	-.153	-.175	-.197			TZ 10.3
0.000	0.000	0.000	0.000	.001	.002	.003	.005	.011	.020	TZ 11.1
.027	.028	.026	.023	.017	.011	.003	-.005	-.014	-.023	TZ 11.2
-.034	-.045	-.055	-.067	-.079	-.090	-.103	-.115			TZ 11.3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	TZ 13.1
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	TZ 13.2
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			TZ 13.3
0.	.182	.253	.345	.405	.452	.526	.653	.858	1.072	WORD 1.1
1.200	1.287	1.351	1.401	1.441	1.476	1.504	1.524	1.537	1.543	WORD 1.2
1.530	1.492	1.421	1.303	1.104	.766	.393	0.			WORD 1.3
0.	.182	.253	.345	.405	.452	.526	.653	.837	1.035	WORD 2.1
1.162	1.252	1.319	1.372	1.415	1.450	1.476	1.496	1.508	1.513	WORD 2.2
1.497	1.446	1.358	1.220	1.029	.747	.390	0.			WORD 2.3
0.	.182	.253	.345	.405	.452	.526	.653	.824	1.018	WORD 3.1
1.138	1.222	1.282	1.327	1.364	1.393	1.419	1.441	1.456	1.461	WORD 3.2
1.442	1.386	1.287	1.122	.912	.660	.357	0.			WORD 3.3
0.	.182	.253	.345	.405	.452	.526	.653	.801	.972	WORD 4.1
1.088	1.172	1.234	1.283	1.321	1.351	1.373	1.390	1.398	1.395	WORD 4.2
1.366	1.309	1.216	1.075	.872	.615	.316	0.			WORD 4.3
0.	.182	.253	.345	.405	.452	.526	.653	.792	.929	WORD 5.1
1.022	1.090	1.148	1.193	1.229	1.262	1.287	1.303	1.312	1.305	WORD 5.2
1.278	1.226	1.142	1.010	.819	.571	.292	0.			WORD 5.3
0.	.182	.253	.345	.405	.452	.526	.653	.779	.914	WORD 6.1
1.004	1.071	1.127	1.171	1.210	1.241	1.266	1.282	1.287	1.277	WORD 6.2
1.248	1.199	1.121	1.004	.821	.578	.299	0.			WORD 6.3
0.	.182	.253	.345	.405	.452	.526	.653	.773	.904	WORD 7.1
.988	1.053	1.104	1.146	1.183	1.217	1.244	1.262	1.268	1.253	WORD 7.2
1.219	1.162	1.077	.949	.765	.538	.276	0.			WORD 7.3

0.	.182	.253	.345	.405	.452	.526	.653	.794	.958	WORD 8.1
1.062	1.133	1.186	1.226	1.255	1.273	1.285	1.292	1.292	1.283	WORD 8.2
1.258	1.217	1.157	1.070	.952	.781	.504	0.			WORD 8.3
0.	.198	.275	.371	.431	.470	.521	.594	.737	.918	WORD 9.1
1.041	1.128	1.197	1.250	1.288	1.316	1.332	1.342	1.336	1.318	WORD 9.2
1.288	1.238	1.171	1.076	.937	.736	.427	0.			WORD 9.3
0.	.198	.275	.371	.431	.470	.521	.594	.741	.937	WORD10.1
1.067	1.158	1.230	1.283	1.321	1.347	1.364	1.372	1.367	1.353	WORD10.2
1.323	1.277	1.210	1.117	.992	.712	.504	0.			WORD10.3
0.	.198	.275	.371	.431	.470	.521	.594	.741	.937	WORD11.1
1.084	1.206	1.302	1.377	1.432	1.469	1.490	1.500	1.491	1.472	WORD11.2
1.437	1.379	1.300	1.192	1.046	.834	.482	0.			WORD11.3
0.	.05918	.06166	.06663	.07161	.07658	.08652	.10641	.15613	.25558	WORD13.1
.35502	.45446	.55390	.65334	.75279	.85223	.95167	1.05111	1.15056	1.25000	WORD13.2
1.236	1.199	1.137	1.046	.914	.727	.437	0.			WORD13.3
0.000	2.503	5.006	10.011	15.017	20.022	22.525	25.028	27.530	30.033	XFUS10
32.536	35.039	37.541	40.044	42.547	45.050	47.552	50.055	52.558	55.061	XFUS20
57.563	60.066	62.569	67.574	72.580	77.586	82.591	87.596	92.602	96.012	XFUS30
0.000	.036	.061	.082	.068	-.145	-.342	-.571	-.821	-1.072	ZFUS10
-1.330	-1.592	-1.852	-2.102	-2.349	-2.576	-2.795	-2.991	-3.153	-3.295	ZFUS20
-3.431	-3.557	-3.674	-3.847	-3.830	-3.654	-3.425	-3.127	-2.688	-2.310	ZFUS30
0.000	.463	1.360	3.670	6.943	9.221	9.498	9.636	9.351	9.148	AFUS10
9.254	9.273	9.341	9.736	9.958	10.302	10.797	10.891	10.894	11.116	AFUS20
11.079	11.131	11.078	10.637	9.698	7.479	5.192	2.520	.744	0.000	AFUS30
59.067	6.453	-5.385								PODORG 1
0.000	3.524	9.639	10.962							XPOD1
.786	.984	.984	.984							RPOD1
60.201	10.606	-5.204								PODORG 2
0.000	3.524	9.639	10.962							XPOD2
.786	.984	.984	.984							RPOD2
62.251	13.888	-4.406	10.718	72.380	13.888	-1.390	1.459			FINORG 1
0.	10.	20.	30.	40.	50.	60.	70.	90.	100.	XFIN
0.	.466	.846	1.138	1.345	1.465	1.498	1.390	.641	0.	FINORD
86.360	0.000	-2.245	9.107	93.783	0.000	.723	2.159			FINORG 2
0.	10.	20.	30.	40.	50.	60.	70.	90.	100.	XFIN
0.	.466	.846	1.138	1.345	1.465	1.498	1.390	.641	0.	FINORD
84.155	.884	-3.133	7.375	90.770	4.605	-4.130	2.210			CANORG
0.	10.	20.	30.	40.	50.	70.	80.	90.	100.	XCAN
0.0	.553	.948	1.264	1.448	1.5	1.264	.948	.553	0.0	CANORD

Table I. - Concluded.

(b) U.S. Customary Units (feet)

```
AST-102 BASELINE FOR AST-200 DESIGN

   1   1  -1   1   1   1      12  28   1  19  30                    2   4   2  10   1  10

8447.                                                                             REFA
0.         .125    .25      .5      .75     1.0     1.5     2.5     5.0     10.    XAF  10
15.        20.     25.      30.     35.     40.     45.     50.     55.     60.    XAF  20
65.        70.     75.      80.     85.     90.     95.     100.                  XAF  28
71.278      5.146-5.087 150.471                                                  WORG  1
75.008      6.215-6.063 146.719                                                  WORG  2
83.830      8.745-7.591 137.845                                                  WORG  3
96.686     12.431-8.981 124.912                                                  WORG  4
118.362    18.647-10.546103.108                                                  WORG  5
127.167    21.171-11.116 94.250                                                  WORG  6
140.037    24.862-11.899 82.389                                                  WORG  7
157.985    30.008-12.635 65.847                                                  WORG  8
171.757    34.795-13.077 53.383                                                  WORG  9
178.946    37.293-13.372 48.401                                                  WORG 10
204.070    46.025-14.301 30.991                                                  WORG 11
234.186    63.412-16.069 16.237                                                  WORG 13
0.000       .001     .001  0.000   -.001   -.002   -.007   -.024   -.120   -.479 TZ 1.1
-1.022    -1.685   -2.435 -3.185  -3.986  -4.787  -5.560  -6.388  -7.120  -7.852 TZ 1.2
-8.487    -9.085   -9.647-10.162 -10.641 -11.074 -11.451 -11.782                 TZ 1.3
0.000       .001     .002   .003    .003    .003    .001   -.006   -.041   -.313 TZ 2.1
-.755     -1.316   -1.956 -2.596  -3.314  -4.032  -4.768  -5.505  -6.158  -6.812 TZ 2.2
-7.392    -7.962   -8.505 -9.049  -9.527  -9.969 -10.337 -10.650                 TZ 2.3
0.000       .003     .006   .012    .018    .023    .034    .053    .083    .064 TZ 3.1
-.396      -.810   -1.312 -1.813  -2.375  -2.936  -3.516  -4.096  -4.653  -5.210 TZ 3.2
-5.716    -6.232   -6.729 -7.198  -7.640  -8.045  -8.413  -8.736                 TZ 3.3
0.000       .005     .009   .018    .028    .036    .051    .078    .130    .053 TZ 4.1
-.159      -.441    -.791 -1.140  -1.543  -1.946  -2.374  -2.803  -3.237  -3.672 TZ 4.2
-4.101    -4.523   -4.937 -5.336  -5.722  -6.091  -6.441  -6.768                 TZ 4.3
0.000       .005     .009   .020    .031    .042    .064    .102    .191    .227 TZ 5.1
 .158       .031    -.156  -.343   -.579   -.816  -1.083  -1.351  -1.637  -1.922 TZ 5.2
-2.214    -2.508   -2.803 -3.096  -3.386  -3.669  -3.948  -4.220                 TZ 5.3
```

0.000	.006	.014	.026	.040	.053	.079	.132	.249	.318	TZ 6.1
.292	.202	.063	-.075	-.261	-.448	-.665	-.880	-1.115	-1.350	TZ 6.2
-1.596	-1.844	-2.092	-2.342	-2.591	-2.838	-3.079	-3.322			TZ 6.3
0.000	.005	.011	.020	.031	.042	.064	.102	.200	.307	TZ 7.1
.317	.273	.190	.106	-.022	-.149	-.304	-.458	-.631	-.804	TZ 7.2
-.985	-1.169	-1.360	-1.551	-1.743	-1.938	-2.132	-2.324			TZ 7.3
0.000	.004	.007	.017	.026	.032	.046	.074	.120	.207	TZ 8.1
.230	.207	.159	.110	.054	-.003	-.098	-.193	-.295	-.396	TZ 8.2
-.506	-.617	-.736	-.856	-.976	-1.097	-1.220	-1.335			TZ 8.3
0.000	.003	.005	.009	.013	.016	.023	.036	.069	.121	TZ 9.1
.158	.166	.152	.139	.104	.070	.022	-.027	-.087	-.146	TZ 9.2
-.214	-.284	-.358	-.435	-.515	-.597	-.682	-.768			TZ 9.3
0.000	.002	.003	.006	.009	.012	.017	.028	.051	.087	TZ 10.1
.112	.121	.113	.106	.080	.055	.016	-.022	-.072	-.122	TZ 10.2
-.178	-.236	-.298	-.364	-.431	-.501	-.573	-.647			TZ 10.3
0.000	0.000	0.000	0.000	.002	.005	.009	.018	.037	.066	TZ 11.1
.087	.092	.084	.076	.056	.037	.010	-.017	-.047	-.077	TZ 11.2
-.110	-.146	-.182	-.219	-.258	-.296	-.338	-.377			TZ 11.3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	TZ 13.1
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	TZ 13.2
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			TZ 13.3
0.	.182	.253	.345	.405	.452	.526	.653	.858	1.072	WORD 1.1
1.200	1.287	1.351	1.401	1.441	1.476	1.504	1.524	1.537	1.543	WORD 1.2
1.530	1.492	1.421	1.303	1.104	.766	.393	0.			WORD 1.3
0.	.182	.253	.345	.405	.452	.526	.653	.837	1.035	WORD 2.1
1.162	1.252	1.319	1.372	1.415	1.450	1.476	1.496	1.508	1.513	WORD 2.2
1.497	1.446	1.358	1.220	1.029	.747	.390	0.			WORD 2.3
0.	.182	.253	.345	.405	.452	.526	.653	.824	1.018	WORD 3.1
1.138	1.222	1.282	1.327	1.364	1.393	1.419	1.441	1.456	1.461	WORD 3.2
1.442	1.386	1.287	1.122	.912	.660	.357	0.			WORD 3.3
0.	.182	.253	.345	.405	.452	.526	.653	.801	.972	WORD 4.1
1.088	1.172	1.234	1.283	1.321	1.351	1.373	1.390	1.398	1.395	WORD 4.2
1.366	1.309	1.216	1.075	.872	.615	.316	0.			WORD 4.3
0.	.182	.253	.345	.405	.452	.526	.653	.792	.929	WORD 5.1
1.022	1.090	1.148	1.193	1.229	1.262	1.287	1.303	1.312	1.305	WORD 5.2
1.278	1.226	1.142	1.010	.819	.571	.292	0.			WORD 5.3
0.	.182	.253	.345	.405	.452	.526	.653	.779	.914	WORD 6.1
1.004	1.071	1.127	1.171	1.210	1.241	1.266	1.282	1.287	1.277	WORD 6.2
1.248	1.199	1.121	1.004	.821	.578	.299	0.			WORD 6.3
0.	.182	.253	.345	.405	.452	.526	.653	.773	.904	WORD 7.1
.988	1.053	1.104	1.146	1.183	1.217	1.244	1.262	1.268	1.253	WORD 7.2
1.219	1.162	1.077	.949	.765	.538	.276	0.			WORD 7.3

```
0.      .182    .253    .345    .405    .452    .526    .653    .794    .958     WORD 8.1
1.062   1.133   1.186   1.226   1.255   1.273   1.285   1.292   1.292   1.283    WORD 8.2
1.258   1.217   1.157   1.070   .952    .781    .504    0.                       WORD 8.3
0.      .198    .275    .371    .431    .470    .521    .594    .737    .918     WORD 9.1
1.041   1.128   1.197   1.250   1.288   1.316   1.332   1.342   1.336   1.318    WORD 9.2
1.288   1.238   1.171   1.076   .937    .736    .427    0.                       WORD 9.3
0.      .198    .275    .371    .431    .470    .521    .594    .741    .937     WORD10.1
1.067   1.158   1.230   1.283   1.321   1.347   1.364   1.372   1.367   1.353    WORD10.2
1.323   1.277   1.210   1.117   .992    .712    .504    0.                       WORD10.3
0.      .198    .275    .371    .431    .470    .521    .594    .741    .937     WORD11.1
1.084   1.206   1.302   1.377   1.432   1.469   1.490   1.500   1.491   1.472    WORD11.2
1.437   1.379   1.300   1.192   1.046   .834    .482    0.                       WORD11.3
0.      .05918  .06166  .06663  .07161  .07658  .08652  .10641  .15613  .25558  WORD13.1
.35502  .45446  .55390  .65334  .75279  .85223  .95167  1.051111.150561.25000   WORD13.2
1.236   1.199   1.137   1.046   .914    .727    .437    0.                       WORD13.3
0.      8.2111  16.422332.844649.266965.689173.900382.111490.322698.5337        XFUS10
106.745114.956123.167131.378139.589147.801156.012164.223172.434180.645          XFUS20
188.856197.067205.279221.701238.123254.546270.968287.390303.812315.             XFUS30
0.      .1191   .1987   .2685   .2227   -.4765  -1.1216-1.8726-2.6924-3.5163     ZFUS10
-4.3621-5.2241-6.0757-6.8973-7.7063-8.4501-9.1687-9.8124-10.344-10.812           ZFUS20
-11.258-11.670-12.053-12.623-12.564-11.988-11.236-10.260-8.8204-7.580            ZFUS30
0.      4.9889  14.638239.508074.730899.2493102.241103.726100.65698.4643         AFUS10
99.609199.8158100.545104.793107.185110.889116.214117.232117.261119.653          AFUS20
119.249119.809119.245114.500104.38880.502155.886427.12248.0117 0.               AFUS30
193.78821.171  -17.667                                                           PODORG 1
0.      11.563  31.624  35.963                                                    XPOD1
2.578   3.229   3.229   3.229                                                     RPOD1
197.51134.795  -17.074                                                            PODORG 2
0.      11.563  31.624  35.963                                                    XPOD2
2.578   3.229   3.229   3.229                                                     RPOD2
204.23745.565  -14.45635.163  237.46745.565  -4.561  4.787                        FINORG 1
0.      10.     20.     30.     40.     50.     60.     70.     90.     100.      XFIN
0.      .466    .846    1.138   1.345   1.465   1.498   1.390   .641    0.        FINORD
283.3330.       -7.367  29.877  307.6870.       2.373   7.082                     FINORG 2
0.      10.     20.     30.     40.     50.     60.     70.     90.     100.      XFIN
0.      .466    .846    1.138   1.345   1.465   1.498   1.390   .641    0.        FINORD
276.1002.900   -10.27824.196  297.80315.1095-13.5507.252                          CANORG
0.      10.     20.     30.     40.     50.     70.     80.     90.     100.      XCAN
0.0     .553    .948    1.264   1.448   1.5     1.264   .948    .553    0.0       CANORD
```

TABLE II. - AST-200 WING DESIGN SUMMARY

- CONSTRAINTS

    - M_∞ = 2.7

    - C_L = 0.10

    - C_m = 0. for CG at $0.49\bar{c}$ at C_L = 0.10

    - $C_p \geq 0.7\ C_{p_{vac}}$ on wing upper surface

    - $\dfrac{dC_p}{dx} \leq$ .0164 per meter (.0050 per foot)

    - Z = -0.095 C_R at wing root trailing edge

    - Wing-nacelle geometry only

- LOADINGS

    - Linear Chordwise, $A_1 x$

    - Quadratic Chordwise, $A_2 x^2$

    - Cubic Chordwise, $A_3 x^3$

    - Quartic Chordwise, $A_4 x^4$

    - Quadratic Spanwise, $A_6 y^2$

    - Cubic Spanwise, $A_7 y^3$

    - Quartic Spanwise, $A_8 y^4$

    - Elliptical, $A_9 \sqrt{1 - 2y/b}/c$

    - Nacelle Bouyancy

- DESIGN CHARACTERISTICS (WING + NACELLES)

    - C_L = 0.10

    - C_{D_i} = .004773

    - C_m = 0.

    - C_{m_0} = 0.0136

    - k_E = 0.477302

Table III. - AST-200 Numerical Model

(a) SI Units (meters)

```
AST-200 CONFIGURATION

  1  1 -1  1  1  1     19 28  1 19 30                          2 20  2 10  1 10

  784.75                                                                  REFA
 0.        .125    .25     .5      .75     1.0    1.5    2.5    5.0   10.   XAF 10
 15.      20.     25.     30.      35.     40.    45.    50.    55.   60.   XAF 20
 65.      70.     75.     80.      85.     90.    95.   100.               XAF 28
  16.256  0.000   -.984  51.366                                          WORG  1
  17.941   .483   -.936  49.671                                          WORG  2
  19.627   .967  -1.193  47.976                                          WORG  3
  22.013  1.651  -1.566  45.579                                          WORG  3A
  22.996  1.933  -1.722  44.585                                          WORG  4
  26.367  2.899  -2.328  41.195                                          WORG  5
  29.736  3.865  -2.858  37.804                                          WORG  6
  33.107  4.832  -3.289  34.415                                          WORG  7
  38.761  6.453  -3.847  28.727                                          WORG  8
  43.218  7.731  -4.238  24.620                                          WORG  9
  48.154  9.146  -4.588  20.070                                          WORG 10
  52.352 10.606  -4.663  16.271                                          WORG 11
  55.203 11.597  -4.641  14.294                                          WORG 12
  57.984 12.563  -4.706  12.368                                          WORG 13
  62.201 14.028  -4.768   9.446                                          WORG 14
  62.201 14.029  -4.768   9.446                                          WORG 15
  64.684 15.463  -4.784   8.229                                          WORG 16
  68.031 17.395  -4.955   6.589                                          WORG 17
  71.380 19.328  -5.228   4.949                                          WORG 18
   0.000  -.000   -.000   -.001   -.001  -.002  -.002  -.004  -.044  -.197 TZ 1.1
   -.430  -.719  -1.046  -1.392  -1.748 -2.101 -2.445 -2.774 -3.083 -3.370 TZ 1.2
  -3.636 -3.880  -4.101  -4.300  -4.478 -4.635 -4.770 -4.880              TZ 1.3
   0.000  -.001   -.002   -.003   -.005  -.006  -.009  -.026  -.085  -.275 TZ 2.1
   -.532  -.835  -1.165  -1.509  -1.857 -2.201 -2.534 -2.851 -3.151 -3.430 TZ 2.2
  -3.690 -3.928  -4.146  -4.344  -4.522 -4.681 -4.819 -4.936              TZ 2.3
   0.000  -.002   -.003   -.006   -.009  -.012  -.018  -.030  -.086  -.273 TZ 3.1
   -.522  -.807  -1.115  -1.433  -1.754 -2.068 -2.373 -2.663 -2.937 -3.193 TZ 3.2
  -3.431 -3.651  -3.854  -4.038  -4.206 -4.357 -4.489 -4.602              TZ 3.3
```

```
 0.000  -.001  -.001  -.002  -.003  -.004  -.007  -.016  -.059  -.223  TZ 3A.1
-.444  -.698  -.969 -1.248 -1.529 -1.805 -2.073 -2.328 -2.571 -2.801  TZ 3A.2
-3.015 -3.216 -3.403 -3.577 -3.737 -3.883 -4.015 -4.132               TZ 3A.3
 0.000  -.000  -.000  -.001  -.001  -.001  -.002  -.011  -.047  -.202  TZ 4.1
-.412  -.653  -.909 -1.172 -1.437 -1.697 -1.949 -2.191 -2.421 -2.639  T7 4.2
-2.844 -3.037 -3.218 -3.386 -3.543 -3.688 -3.820 -3.938               TZ 4.3
 0.000   .001   .001   .002   .004   .005   .008   .008  -.012  -.124  T7 5.1
-.280  -.462  -.658  -.860 -1.065 -1.268 -1.466 -1.659 -1.846 -2.024  TZ 5.2
-2.195 -2.360 -2.517 -2.667 -2.810 -2.946 -3.074 -3.193               TZ 5.3
 0.000   .001   .002   .005   .008   .010   .015   .026   .018  -.047  TZ 6.1
-.153  -.281  -.422  -.572  -.724  -.877 -1.031 -1.181 -1.329 -1.474  TZ 6.2
-1.616 -1.755 -1.891 -2.025 -2.155 -2.282 -2.405 -2.523               TZ 6.3
 0.000   .002   .003   .006   .009   .012   .019   .031   .050   .022  T7 7.1
-.043  -.127  -.224  -.328  -.438  -.551  -.666  -.782  -.899 -1.016  TZ 7.2
-1.133 -1.250 -1.367 -1.485 -1.602 -1.718 -1.833 -1.947               TZ 7.3
 0.000   .002   .004   .007   .011   .014   .021   .036   .066   .085  TZ 8.1
 .073   .041  -.001  -.054  -.111  -.174  -.241  -.313  -.387  -.465  T7 8.2
-.547  -.630  -.716  -.805  -.895  -.988 -1.082 -1.177               T7 8.3
 0.000   .002   .004   .008   .012   .016   .023   .039   .070   .101  T7 9.1
 .109   .103   .086   .062   .030  -.007  -.050  -.096  -.146  -.200  TZ 9.2
-.257  -.317  -.381  -.447  -.517  -.589  -.663  -.740               TZ 9.3
 0.000   .002   .003   .005   .008   .011   .017   .028   .055   .091  TZ 10.1
 .108   .114   .113   .107   .095   .079   .059   .036   .009  -.021  TZ 10.2
-.054  -.090  -.128  -.170  -.214  -.261  -.309  -.359               TZ 10.3
 0.000   .001   .002   .003   .004   .006   .009   .015   .030   .056  TZ 11.1
 .068   .074   .076   .070   .062   .051   .035   .018  -.002  -.026  TZ 11.2
-.051  -.077  -.108  -.140  -.173  -.208  -.246  -.284               T7 11.3
 0.000   .001   .001   .002   .004   .005   .007   .012   .025   .045  TZ 12.1
 .057   .063   .067   .062   .056   .048   .037   .023   .007  -.010  TZ 12.2
-.031  -.052  -.075  -.100  -.126  -.154  -.183  -.213               TZ 12.3
 0.000   .001   .001   .002   .003   .004   .006   .010   .020   .035  TZ 13.1
 .048   .055   .059   .059   .057   .052   .047   .037   .028   .016  TZ 13.2
 .003  -.012  -.028  -.045  -.062  -.080  -.098  -.118               TZ 13.3
 0.000   .000   .000   .001   .001   .001   .002   .003   .006   .015  TZ 14.1
 .025   .031   .034   .036   .036   .036   .035   .034   .032   .029  TZ 14.2
 .027   .023   .020   .017   .013   .009   .005  0.000               TZ 14.3
 0.000   .000   .000   .001   .001   .001   .002   .003   .006   .015  TZ 15.1
 .025   .031   .034   .036   .036   .036   .035   .034   .032   .029  TZ 15.2
 .027   .023   .020   .017   .013   .009   .005  0.000               TZ 15.3
 0.000  -.000  -.001  -.002  -.002  -.003  -.004  -.007  -.014  -.028  TZ 16.1
-.042  -.051  -.056  -.062  -.068  -.073  -.079  -.085  -.091  -.097  TZ 16.2
```

										Label
-.103	-.108	-.114	-.119	-.125	-.130	-.136	-.141			TZ 16.3
0.000	-.000	-.001	-.002	-.002	-.003	-.004	-.007	-.015	-.029	TZ 17.1
-.044	-.058	-.073	-.083	-.092	-.102	-.112	-.118	-.125	-.132	TZ 17.2
-.139	-.144	-.150	-.156	-.161	-.166	-.171	-.176			TZ 17.3
0.000	-.000	-.001	-.002	-.002	-.003	-.004	-.007	-.014	-.028	TZ 18.1
-.042	-.048	-.055	-.061	-.067	-.073	-.075	-.077	-.079	-.082	TZ 18.2
-.083	-.082	-.080	-.080	-.078	-.076	-.071	-.067			TZ 18.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD1.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD1.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD1.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD2.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD2.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD2.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD3.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD3.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD3.3
0.	.137	.179	.241	.297	.339	.412	.523	.724	.994	WORD3A.1
1.177	1.315	1.416	1.487	1.528	1.539	1.539	1.539	1.539	1.539	WORD3A.2
1.384	1.210	1.018	.817	.614	.412	.211	0.			WORD3A.3
0.	.136	.178	.237	.291	.333	.405	.514	.712	.978	WORD4.1
1.157	1.292	1.391	1.461	1.501	1.512	1.512	1.512	1.512	1.512	WORD4.2
1.363	1.192	1.003	.806	.606	.406	.208	0.			WORD4.3
0.	.128	.168	.225	.277	.316	.386	.490	.679	.931	WORD5.1
1.103	1.232	1.326	1.392	1.430	1.441	1.441	1.441	1.441	1.437	WORD5.2
1.294	1.132	.953	.765	.576	.385	.197	0.			WORD5.3
0.	.118	.160	.216	.266	.304	.370	.470	.651	.894	WORD6.1
1.059	1.182	1.273	1.336	1.373	1.383	1.383	1.383	1.383	1.341	WORD6.2
1.208	1.056	.889	.714	.537	.360	.184	0.			WORD6.3
0.	.110	.153	.208	.257	.294	.358	.455	.631	.866	WORD7.1
1.025	1.144	1.231	1.293	1.328	1.338	1.338	1.338	1.338	1.277	WORD7.2
1.151	1.006	.848	.681	.512	.343	.175	0.			WORD7.3
0.	.101	.145	.200	.247	.283	.344	.438	.607	.833	WORD8.1
.987	1.101	1.184	1.244	1.278	1.287	1.287	1.287	1.287	1.186	WORD8.2
1.069	.935	.788	.633	.476	.319	.163	0.			WORD8.3
0.	.100	.144	.198	.245	.280	.341	.435	.602	.827	WORD9.1
.979	1.092	1.175	1.234	1.268	1.277	1.277	1.277	1.260	1.161	WORD9.2
1.046	.915	.771	.619	.466	.312	.159	0.			WORD9.3
0.	.102	.146	.201	.248	.284	.345	.440	.609	.836	WORD10.1
.990	1.105	1.189	1.248	1.283	1.292	1.292	1.292	1.247	1.149	WORD10.2
1.035	.906	.763	.613	.461	.309	.156	0.			WORD10.3

0.	.111	.154	.209	.258	.295	.359	.457	.632	.868	WORD11.1
1.028	1.148	1.235	1.297	1.330	1.342	1.342	1.342	1.263	1.164	WORD11.2
1.049	.917	.773	.621	.467	.313	.160	0.			WORD11.3
0.	.118	.160	.216	.266	.304	.370	.470	.651	.894	WORD12.1
1.059	1.181	1.272	1.335	1.372	1.382	1.382	1.382	1.300	1.198	WORD12.2
1.080	.945	.796	.639	.481	.322	.164	0.			WORD12.3
0.	.125	.166	.222	.274	.313	.381	.484	.670	.920	WORD13.1
1.090	1.216	1.309	1.375	1.413	1.423	1.423	1.423	1.339	1.234	WORD13.2
1.112	.972	.819	.658	.495	.331	.169	0.			WORD13.3
0.	.138	.177	.235	.289	.330	.402	.510	.706	.969	WORD14.1
1.148	1.282	1.380	1.449	1.489	1.500	1.500	1.500	1.411	1.300	WORD14.2
1.171	1.024	.862	.692	.521	.349	.178	0.			WORD14.3
0.	.0069	.0144	.0294	.0440	.0590	.0884	.1462	.2853	.541	WORD15.1
.766	.961	1.126	1.261	1.365	1.440	1.485	1.500	1.485	1.440	WORD15.2
1.365	1.261	1.126	.961	.766	.541	.285	0.			WORD15.3
0.	.0069	.0144	.0294	.0440	.0590	.0884	.1462	.2853	.541	WORD16.1
.766	.961	1.126	1.261	1.365	1.440	1.485	1.500	1.485	1.440	WORD16.2
1.365	1.261	1.126	.961	.766	.541	.285	0.			WORD16.3
0.	.0069	.0144	.0294	.0440	.0590	.0884	.1462	.2853	.541	WORD17.1
.766	.961	1.126	1.261	1.365	1.440	1.485	1.500	1.485	1.440	WORD17.2
1.365	1.261	1.126	.961	.766	.541	.285	0.			WORD17.3
0.	.0069	.0144	.0294	.0440	.0590	.0884	.1462	.2853	.541	WORD18.1
.766	.961	1.126	1.261	1.365	1.440	1.485	1.500	1.485	1.440	WORD18.2
1.365	1.261	1.126	.961	.766	.541	.285	0.			WORD18.3
0.000	3.048	6.096	9.144	12.192	15.240	18.288	21.336	24.384	27.432	XFUS 10
30.480	33.528	36.576	39.624	42.672	45.720	48.768	51.816	54.864	57.912	XFUS 20
60.960	64.008	67.056	70.104	73.152	76.200	79.248	85.344	91.440	96.012	XFUS 30
0.000	0.000	0.000	0.000	0.000	-.061	-.144	-.340	-.585	-.930	ZFUS 10
-1.324	-1.729	-2.129	-2.512	-2.875	-3.207	-3.520	-3.801	-4.069	-4.309	ZFUS 20
-4.521	-4.709	-4.876	-4.999	-5.044	-5.014	-4.907	-4.557	-4.023	-3.536	ZFUS 30
0.000	.660	1.839	3.298	5.045	7.061	9.021	10.043	10.294	9.838	AFUS 10
9.216	9.188	9.346	9.569	9.866	10.247	10.702	10.990	11.074	11.148	AFUS 20
11.130	10.981	10.591	9.968	9.114	7.887	6.550	3.252	.929	0.000	AFUS 30
59.067	6.453	-6.004								PODORG 1
0.000	.610	1.219	1.829	2.438	3.048	3.658	4.267	4.877	5.486	XPOD
6.096	6.706	7.315	7.925	8.534	9.144	9.639	9.754	10.363	10.962	XPOD
.786	.798	.811	.824	.836	.849	.861	.874	.886	.899	RPOD
.911	.924	.936	.949	.961	.974	.984	.984	.984	.984	RPOD

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60.201 10.606 -5.906                                                    PODORG 2
 0.000    .610   1.219   1.829    2.438    3.048    3.658    4.267    4.877   5.486  XPOD
 6.096   6.706   7.315   7.925    8.534    9.144    9.639    9.754  10.363 10.962    XPOD
  .786    .798    .811    .824     .836     .849     .861     .874     .886    .899  RPOD
  .911    .924    .936    .949     .961     .974     .984     .984     .984    .984  RPOD
62.251 14.029  -4.768  10.718  72.380  14.029   -1.752   1.459                      V FIN
0.       10.     20.     30.      40.      50.      60.      70.      90.     100.   XFIN
0.       .466    .846   1.138    1.345    1.465    1.498    1.390     .641    0.     FINORD
86.359  0.000   -3.475   9.107  93.783   0.000    -.506   2.159                     V TAIL
0.       10.     20.     30.      40.      50.      60.      70.      90.     100.   XVTAIL
0.       .466    .846   1.138    1.345    1.465    1.498    1.390     .641    0.     TVTAIL
84.155   .884   -4.237   7.375  90.770   4.606   -5.234   2.210                     H TAIL
0.       10.     20.     30.      40.      50.      70.      80.      90.     100.   XHTAIL
0.0      .553    .948   1.264    1.448    1.5      1.264     .948     .553    0.0    THTAIL
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Table III. - Concluded.

(b) U.S. Customary Units (feet)

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AST-200 CONFIGURATION

  1   1 -1   1   1   1      19 28   1 19 30                              2 20  2 10  1 10

8447.                                                                                  REFA
0.        .125    .25    .5       .75     1.0     1.5     2.5     5.0    10.            XAF 10
  15.      20.    25.    30.      35.     40.     45.     50.     55.    60.            XAF 20
 65.       70.    75.    80.      85.     90.     95.    100.                           XAF 28
 53.333 0.       -3.227 168.524                                                        WORG 1
 58.861 1.585    -3.070 162.963                                                        WORG 2
 64.392 3.171    -3.914 157.401                                                        WORG 3
 72.221 5.416    -5.137 149.537                                                        WORG 3A
 75.447 6.341    -5.650 146.276                                                        WORG 4
 86.505 9.512    -7.639 135.155                                                        WORG 5
 97.560 12.682   -9.376 124.030                                                        WORG 6
108.61915.853   -10.790112.909                                                         WORG 7
127.16721.171   -12.62094.250                                                          WORG 8
141.79125.365   -13.90480.773                                                          WORG 9
157.98530.008   -15.05165.847                                                          WORG 10
171.75734.795   -15.29753.383                                                          WORG 11
181.11338.047   -15.22646.897                                                          WORG 12
190.23741.218   -15.43840.576                                                          WORG 13
204.07046.025   -15.64430.991                                                          WORG 14
204.07046.026   -15.64430.991                                                          WORG 15
212.21750.730   -15.69526.999                                                          WORG 16
223.20057.071   -16.25621.618                                                          WORG 17
234.18663.412   -17.15216.237                                                          WORG 18
0.        -.001  -.001  -.002   -.003   -.005   -.007   -.012   -.144   -.647          TZ 1.1
-1.410 -2.359 -3.431 -4.568 -5.734 -6.894 -8.022 -9.100 -10.114-11.058                 TZ 1.2
-11.930-12.729-13.454-14.109-14.693-15.207-15.649-16.010                               TZ 1.3
0.        -.002  -.005  -.010   -.015   -.020   -.030   -.085   -.278   -.901          TZ 2.1
-1.745 -2.738 -3.821 -4.950 -6.093 -7.221 -8.313 -9.355 -10.337-11.254                 TZ 2.2
-12.105-12.888-13.602-14.252-14.836-15.357-15.811-16.193                               TZ 2.3
0.        -.005  -.010  -.019   -.029   -.039   -.058   -.097   -.282   -.897          TZ 3.1
-1.711 -2.647 -3.658 -4.703 -5.753 -6.785 -7.784 -8.736 -9.635 -10.476                 TZ 3.2
-11.257-11.979-12.643-13.249-13.799-14.293-14.728-15.098                               TZ 3.3
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0.      -.002  -.004  -.007  -.011  -.014  -.023  -.054  -.192  -.731       TZ 3A.1
-1.456 -2.290 -3.180 -4.096 -5.016 -5.922 -6.800 -7.639 -8.436 -9.188       TZ 3A.2
-9.893 -10.552-11.166-11.734-12.259-12.739-13.173-13.555                    TZ 3A.3
0.      -.001  -.001  -.002  -.003  -.004  -.008  -.036  -.155  -.662       TZ 4.1
-1.351 -2.143 -2.983 -3.846 -4.713 -5.566 -6.394 -7.187 -7.942 -8.657       TZ 4.2
-9.331 -9.964 -10.557-11.110-11.625-12.099-12.532-12.919                    TZ 4.3
0.       .002   .004   .008   .012   .017   .025   .027  -.041  -.406       TZ 5.1
-.918  -1.516 -2.158 -2.822 -3.494 -4.160 -4.810 -5.443 -6.055 -6.640       TZ 5.2
-7.202 -7.742 -8.257 -8.749 -9.219 -9.665 -10.084-10.475                    TZ 5.3
0.       .004   .008   .017   .025   .034   .050   .084   .059  -.154       TZ 6.1
-.503  -.921  -1.385 -1.877 -2.376 -2.878 -3.381 -3.874 -4.360 -4.836       TZ 6.2
-5.302 -5.759 -6.205 -6.643 -7.070 -7.487 -7.889 -8.277                     TZ 6.3
0.       .005   .010   .021   .031   .041   .062   .103   .163   .071       TZ 7.1
-.141  -.418  -.735  -1.076 -1.438 -1.809 -2.186 -2.567 -2.948 -3.333       TZ 7.2
-3.716 -4.100 -4.486 -4.871 -5.255 -5.638 -6.015 -6.388                     TZ 7.3
0.       .006   .012   .023   .035   .047   .070   .117   .216   .280       TZ 8.1
.241     .135  -.002  -.176  -.364  -.570  -.792  -1.026 -1.270 -1.527      TZ 8.2
-1.793 -2.067 -2.350 -2.640 -2.937 -3.242 -3.550 -3.862                     TZ 8.3
0.       .006   .013   .025   .038   .051   .076   .127   .229   .330       TZ 9.1
.356     .339   .283   .205   .098  -.024  -.164  -.315  -.480  -.655       TZ 9.2
-.843  -1.041 -1.250 -1.468 -1.697 -1.933 -2.176 -2.427                     TZ 9.3
0.       .005   .009   .018   .027   .037   .056   .092   .182   .299       TZ 10.1
.354     .374   .370   .350   .311   .259   .194   .118   .030  -.068       TZ 10.2
-.177  -.295  -.421  -.558  -.703  -.855  -1.013 -1.179                     TZ 10.3
0.       .002   .005   .010   .014   .019   .029   .048   .097   .184       TZ 11.1
.223     .244   .248   .230   .202   .167   .116   .058  -.007  -.084       TZ 11.2
-.166  -.254  -.354  -.458  -.567  -.683  -.806  -.932                      TZ 11.3
0.       .002   .004   .008   .012   .016   .024   .041   .081   .147       TZ 12.1
.187     .207   .219   .203   .184   .158   .120   .074   .022  -.034       TZ 12.2
-.101  -.172  -.246  -.329  -.415  -.505  -.599  -.698                      TZ 12.3
0.       .002   .003   .007   .010   .013   .020   .034   .067   .116       TZ 13.1
.158     .179   .194   .193   .187   .171   .153   .123   .092   .052       TZ 13.2
.011    -.040  -.092  -.148  -.204  -.263  -.322  -.387                     TZ 13.3
0.       .001   .001   .002   .003   .004   .006   .010   .020   .049       TZ 14.1
.081     .101   .112   .118   .118   .117   .115   .111   .104   .096       TZ 14.2
.087     .077   .066   .055   .043   .029   .015   0.                       TZ 14.3
0.       .001   .001   .002   .003   .004   .006   .010   .020   .049       TZ 15.1
.081     .101   .112   .118   .118   .117   .115   .111   .104   .096       TZ 15.2
.087     .077   .066   .055   .043   .029   .015   0.                       TZ 15.3
0.      -.001  -.002  -.005  -.007  -.009  -.014  -.023  -.046  -.092       TZ 16.1
-.139  -.166  -.184  -.203  -.222  -.241  -.260  -.279  -.299  -.318        TZ 16.2
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-.337	-.355	-.374	-.392	-.409	-.427	-.446	-.464			TZ 16.3
0.	-.001	-.002	-.005	-.007	-.010	-.014	-.024	-.048	-.095	TZ 17.1
-.143	-.190	-.238	-.271	-.303	-.336	-.366	-.388	-.411	-.434	TZ 17.2
-.455	-.474	-.493	-.513	-.529	-.545	-.562	-.577			TZ 17.3
0.	-.001	-.002	-.005	-.007	-.009	-.014	-.023	-.047	-.093	TZ 18.1
-.138	-.159	-.179	-.200	-.220	-.238	-.246	-.253	-.260	-.268	TZ 18.2
-.272	-.268	-.264	-.261	-.257	-.249	-.234	-.219			TZ 18.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD1.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD1.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD1.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD2.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD2.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD2.3
0.	.137	.180	.242	.298	.339	.413	.521	.726	.996	WORD3.1
1.181	1.318	1.419	1.490	1.532	1.543	1.543	1.543	1.543	1.543	WORD3.2
1.388	1.213	1.021	.819	.615	.413	.212	0.			WORD3.3
0.	.137	.179	.241	.297	.339	.412	.523	.724	.994	WORD3A.1
1.177	1.315	1.416	1.487	1.528	1.539	1.539	1.539	1.539	1.539	WORD3A.2
1.384	1.210	1.018	.817	.614	.412	.211	0.			WORD3A.3
0.	.136	.178	.237	.291	.333	.405	.514	.712	.978	WORD4.1
1.157	1.292	1.391	1.461	1.501	1.512	1.512	1.512	1.512	1.512	WORD4.2
1.363	1.192	1.003	.806	.606	.406	.208	0.			WORD4.3
0.	.128	.168	.225	.277	.316	.386	.490	.679	.931	WORD5.1
1.103	1.232	1.326	1.392	1.430	1.441	1.441	1.441	1.441	1.437	WORD5.2
1.294	1.132	.953	.765	.576	.385	.197	0.			WORD5.3
0.	.118	.160	.216	.266	.304	.370	.470	.651	.894	WORD6.1
1.059	1.182	1.273	1.336	1.373	1.383	1.383	1.383	1.383	1.341	WORD6.2
1.208	1.056	.889	.714	.537	.360	.184	0.			WORD6.3
0.	.110	.153	.208	.257	.294	.358	.455	.631	.866	WORD7.1
1.025	1.144	1.231	1.293	1.328	1.338	1.338	1.338	1.338	1.277	WORD7.2
1.151	1.006	.848	.681	.512	.343	.175	0.			WORD7.3
0.	.101	.145	.200	.247	.283	.344	.438	.607	.833	WORD8.1
.987	1.101	1.184	1.244	1.278	1.287	1.287	1.287	1.287	1.186	WORD8.2
1.069	.935	.788	.633	.476	.319	.163	0.			WORD8.3
0.	.100	.144	.198	.245	.280	.341	.435	.602	.827	WORD9.1
.979	1.092	1.175	1.234	1.268	1.277	1.277	1.277	1.260	1.161	WORD9.2
1.046	.915	.771	.619	.466	.312	.159	0.			WORD9.3
0.	.102	.146	.201	.248	.284	.345	.440	.609	.836	WORD10.1
.990	1.105	1.189	1.248	1.283	1.292	1.292	1.292	1.247	1.149	WORD10.2
1.035	.906	.763	.613	.461	.309	.156	0.			WORD10.3

```
0.      .111    .154    .209    .258    .295    .359    .457    .632    .868     WORD11.1
1.028   1.148   1.235   1.297   1.330   1.342   1.342   1.342   1.263   1.164    WORD11.2
1.049   .917    .773    .621    .467    .313    .160    0.                       WORD11.3
0.      .118    .160    .216    .266    .304    .370    .470    .651    .894     WORD12.1
1.059   1.181   1.272   1.335   1.372   1.382   1.382   1.382   1.300   1.198    WORD12.2
1.080   .945    .796    .639    .481    .322    .164    0.                       WORD12.3
0.      .125    .166    .222    .274    .313    .381    .484    .670    .920     WORD13.1
1.090   1.216   1.309   1.375   1.413   1.423   1.423   1.423   1.339   1.234    WORD13.2
1.112   .972    .819    .658    .495    .331    .169    0.                       WORD13.3
0.      .138    .177    .235    .289    .330    .402    .510    .706    .969     WORD14.1
1.148   1.282   1.380   1.449   1.489   1.500   1.500   1.500   1.411   1.300    WORD14.2
1.171   1.024   .862    .692    .521    .349    .178    0.                       WORD14.3
0.      .0069   .0144   .0294   .0440   .0590   .0884   .1462   .2853   .541     WORD15.1
.766    .961    1.126   1.261   1.365   1.440   1.485   1.500   1.485   1.440    WORD15.2
1.365   1.261   1.126   .961    .766    .541    .285    0.                       WORD15.3
0.      .0069   .0144   .0294   .0440   .0590   .0884   .1462   .2853   .541     WORD16.1
.766    .961    1.126   1.261   1.365   1.440   1.485   1.500   1.485   1.440    WORD16.2
1.365   1.261   1.126   .961    .766    .541    .285    0.                       WORD16.3
0.      .0069   .0144   .0294   .0440   .0590   .0884   .1462   .2853   .541     WORD17.1
.766    .961    1.126   1.261   1.365   1.440   1.485   1.500   1.485   1.440    WORD17.2
1.365   1.261   1.126   .961    .766    .541    .285    0.                       WORD17.3
0.      .0069   .0144   .0294   .0440   .0590   .0884   .1462   .2853   .541     WORD18.1
.766    .961    1.126   1.261   1.365   1.440   1.485   1.500   1.485   1.440    WORD18.2
1.365   1.261   1.126   .961    .766    .541    .285    0.                       WORD18.3
0.      10.     20.     30.     40.     50.     60.     70.     80.     90.      XFUS 10
100.    110.    120.    130.    140.    150.    160.    170.    180.    190.     XFUS 20
200.    210.    220.    230.    240.    250.    260.    280.    300.    315.     XFUS 30
0.      0.      0.      0.      0.      -.200   -.471   -1.117  -1.920  -3.050   ZFUS 10
-4.345  -5.671  -6.986  -8.240  -9.434  -10.522 -11.548 -12.471 -13.349 -14.136  ZFUS 20
-14.834 -15.451 -15.999 -16.400 -16.550 -16.450 -16.100 -14.950 -13.200 -11.600  ZFUS 30
0.0     7.1     19.8    35.5    54.3    76.0    97.1    108.1   110.8   105.9    AFUS 10
99.2    98.9    100.6   103.0   106.2   110.3   115.2   118.3   119.2   120.0    AFUS 20
119.8   118.2   114.0   107.3   98.1    84.9    70.5    35.0    10.0    0.0      AFUS 30
193.788 21.171  -19.698                                                         PODORG 1
0.      2.      4.      6.      8.      10.     12.     14.     16.     18.      XPOD
20.     22.     24.     26.     28.     30.     31.624  32.     34.     35.963   XPOD
2.578   2.619   2.660   2.702   2.743   2.784   2.825   2.866   2.907   2.949    RPOD
2.990   3.031   3.072   3.113   3.154   3.196   3.229   3.229   3.229   3.229    RPOD
```

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197.51134.795 -19.375                                                    PODORG 2
0.       2.      4.      6.      8.      10.     12.     14.     16.     18.      XPOD
20.      22.     24.     26.     28.     30.     31.624 32.     34.     35.963   XPOD
2.578   2.619   2.660   2.702   2.743   2.784   2.825   2.866   2.907   2.949    RPOD
2.990   3.031   3.072   3.113   3.154   3.196   3.229   3.229   3.229   3.229    RPOD
204.23746.0255-15.64435.163 237.46746.0255-5.749 4.787                           V FIN
0.       10.     20.     30.     40.     50.     60.     70.     90.     100.     XFIN
0.       .466    .846    1.138   1.345   1.465   1.498   1.390   .641    0.       FINORD
283.3300.        -11.40029.877 307.6870.         -1.660 7.082                     V TAIL
0.       10.     20.     30.     40.     50.     60.     70.     90.     100.     XVTAIL
0.       .466    .846    1.138   1.345   1.465   1.498   1.390   .641    0.       TVTAIL
276.1002.900    -13.90024.196 297.80315.110 -17.1727.252                          H TAIL
0.       10.     20.     30.     40.     50.     70.     80.     90.     100.     XHTAIL
0.0      .553    .948    1.264   1.448   1.5     1.264   .948    .553    0.0      THTAIL
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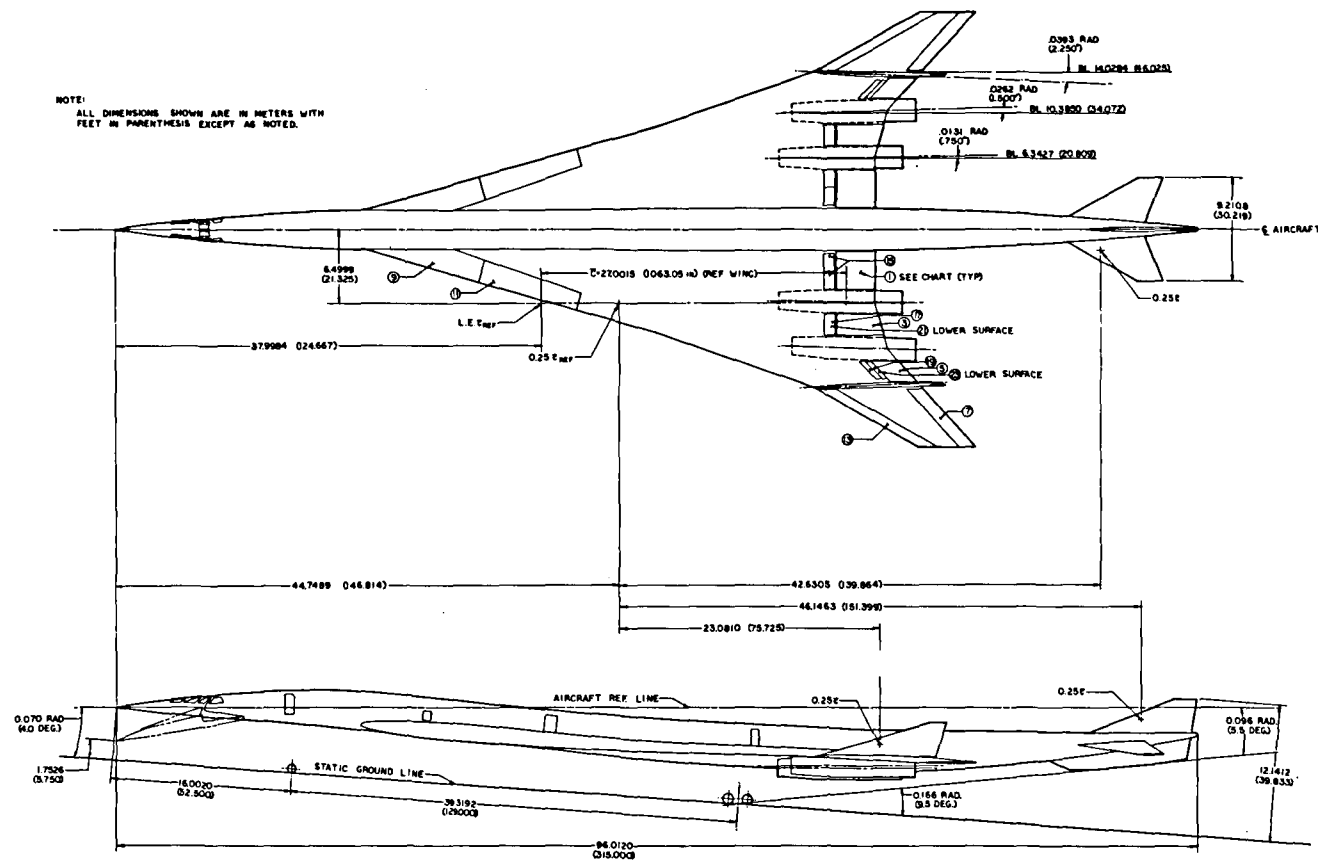
Figure 1. AST-102 baseline configuration.

AST-102

3.524
(11.563)
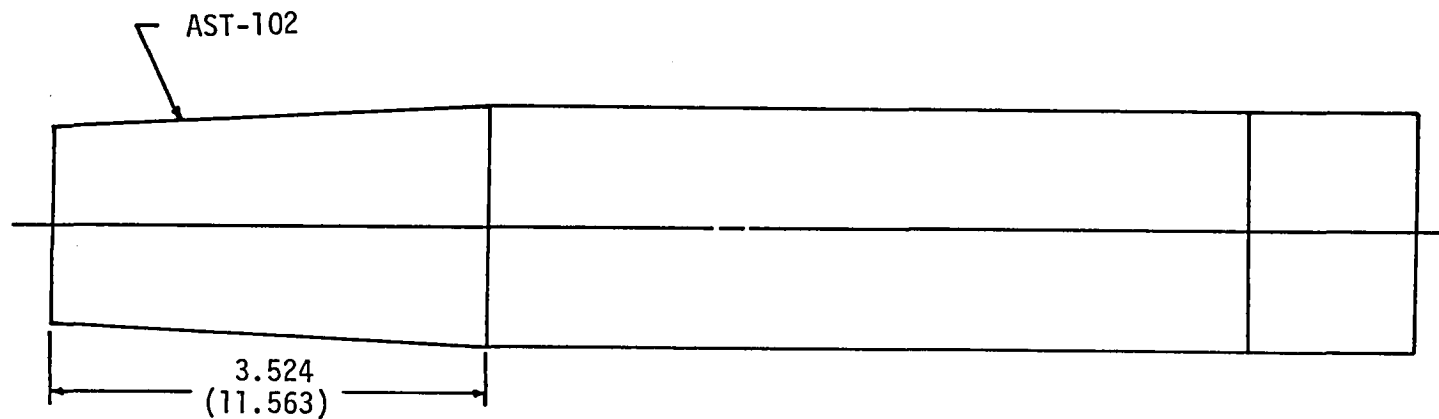
NOTE: Dimensions in meters with
feet in parentheses.

AST-200

1.572
(5.156)

1.968
(6.458)

9.639
(31.624)

10.962
(35.963)
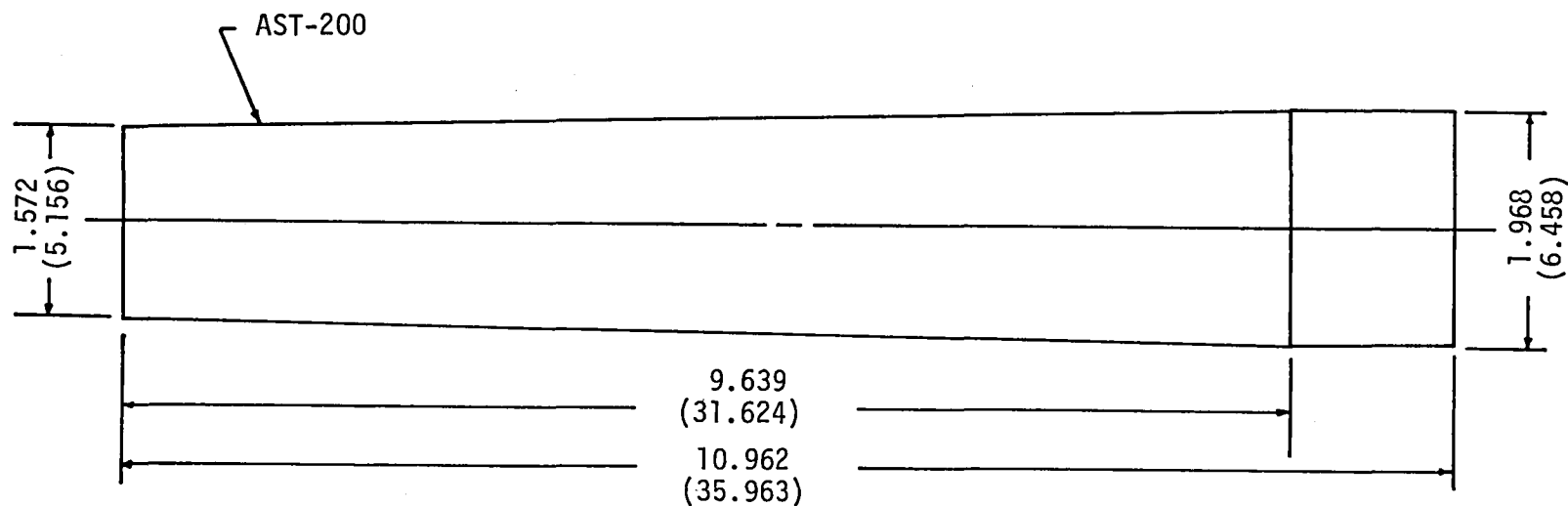
Figure 2. - Nacelle revision.
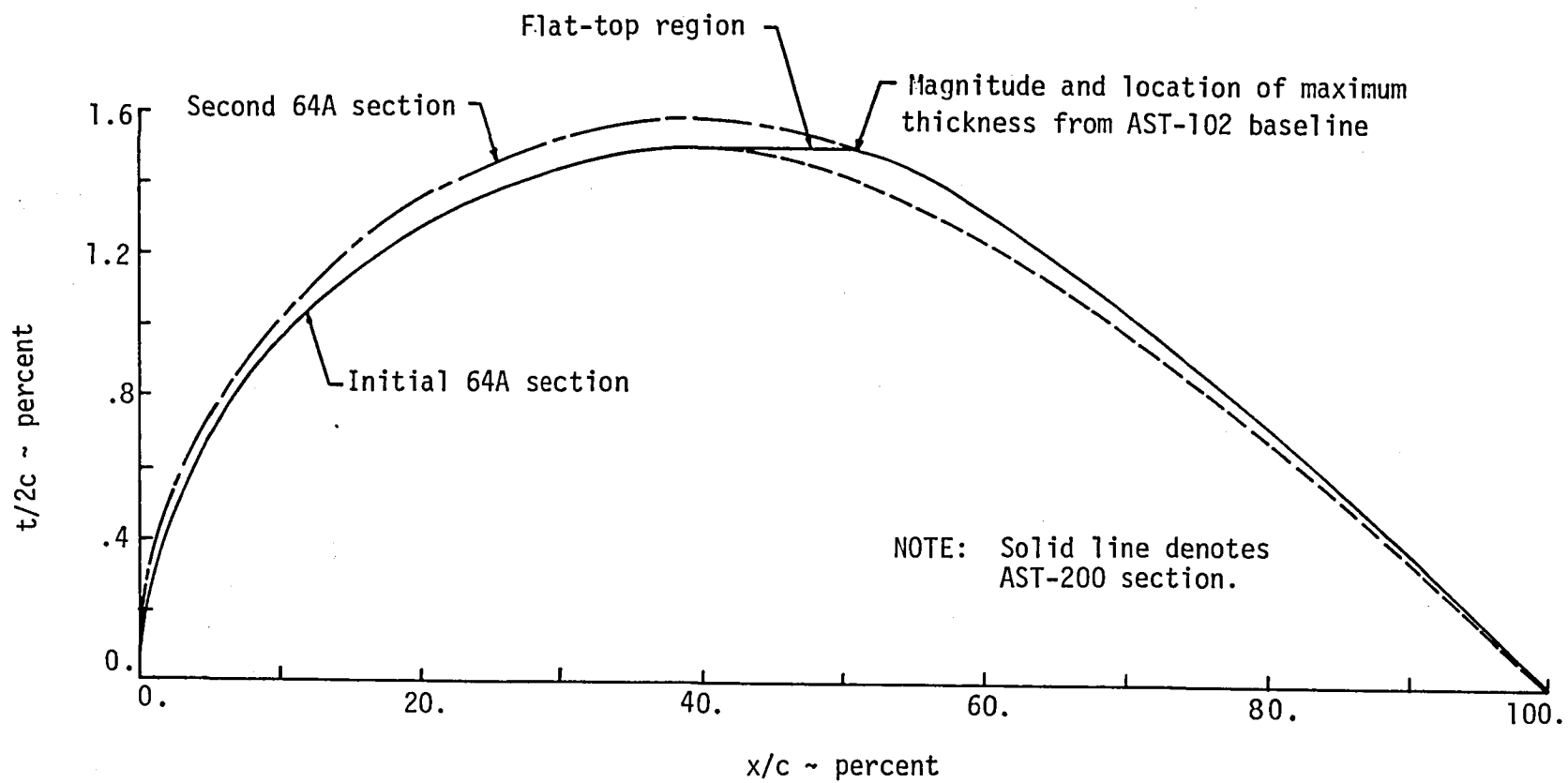
Figure 3. - Typical AST-200 wing section development.
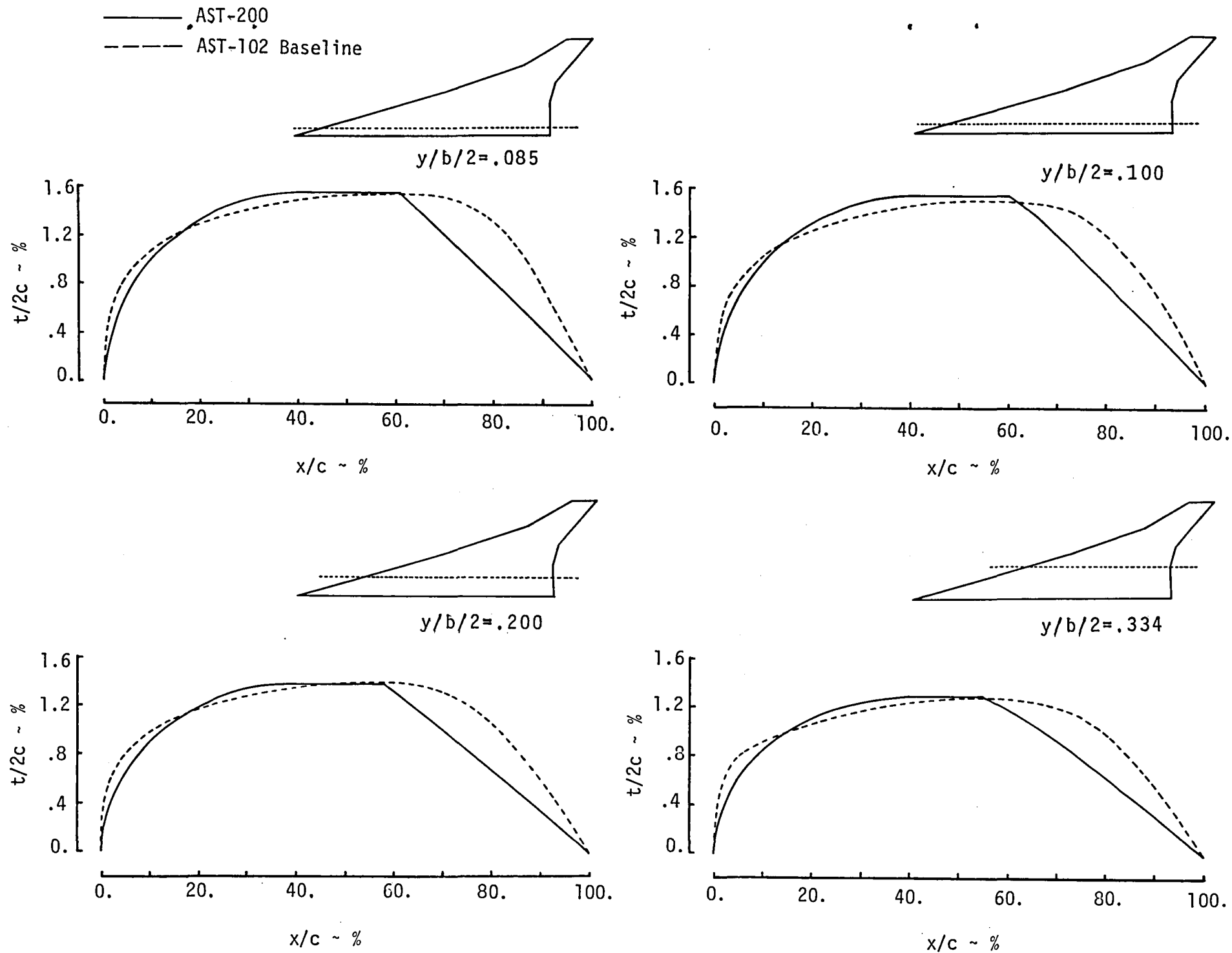
(a) Inboard sections.

Figure 4. - Typical comparison of baseline and revised wing thickness distributions.
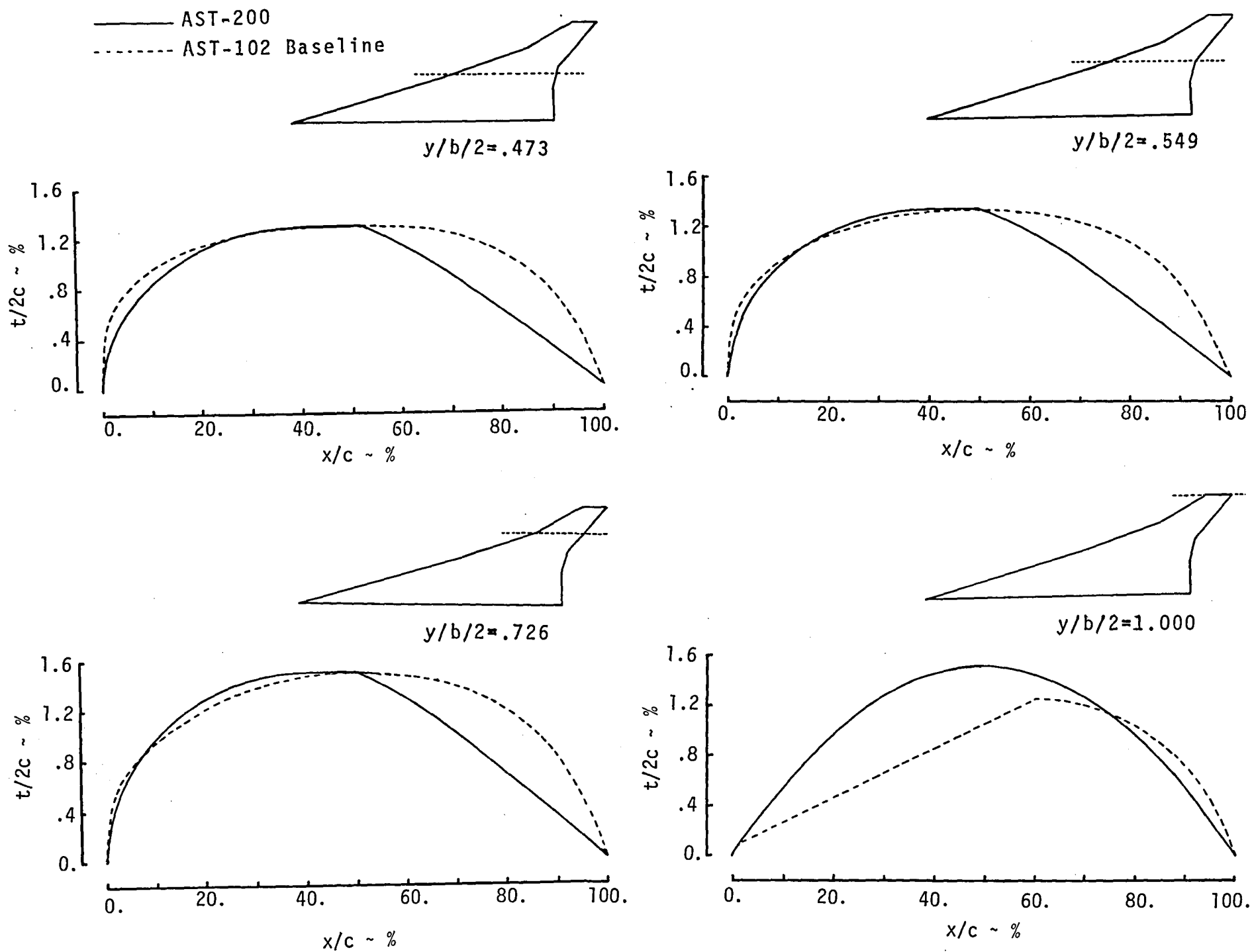
(b) Outboard sections.

Figure 4. - Concluded.
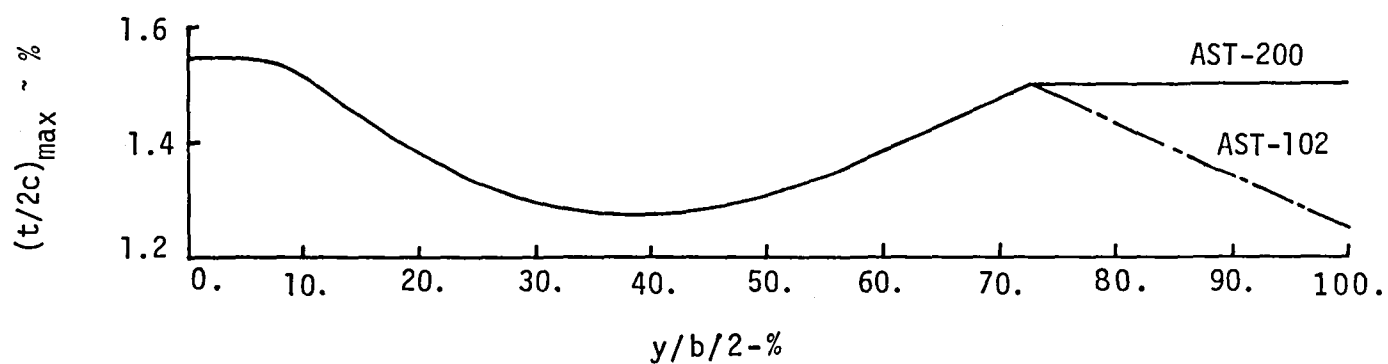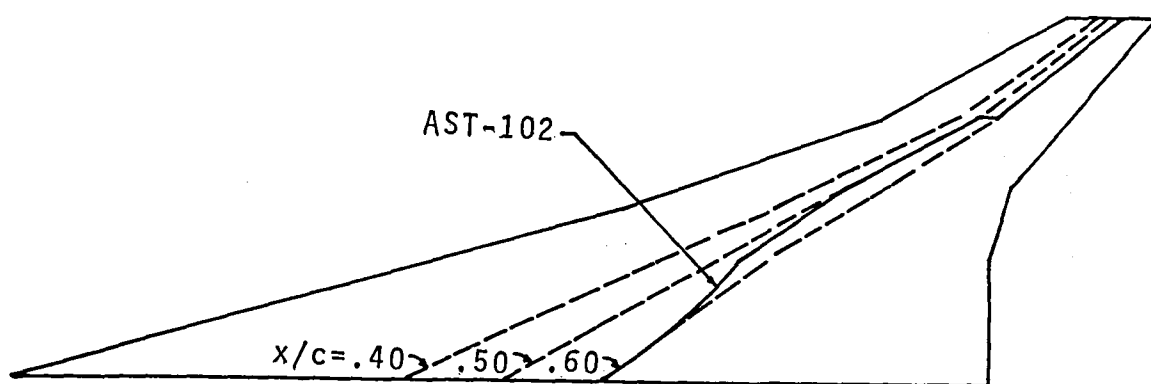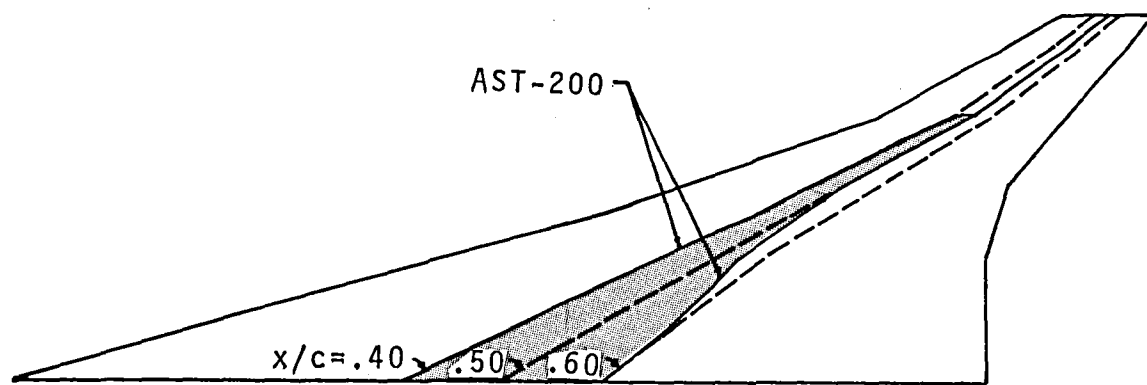
Figure 5. - Spanwise variation of maximum thickness.
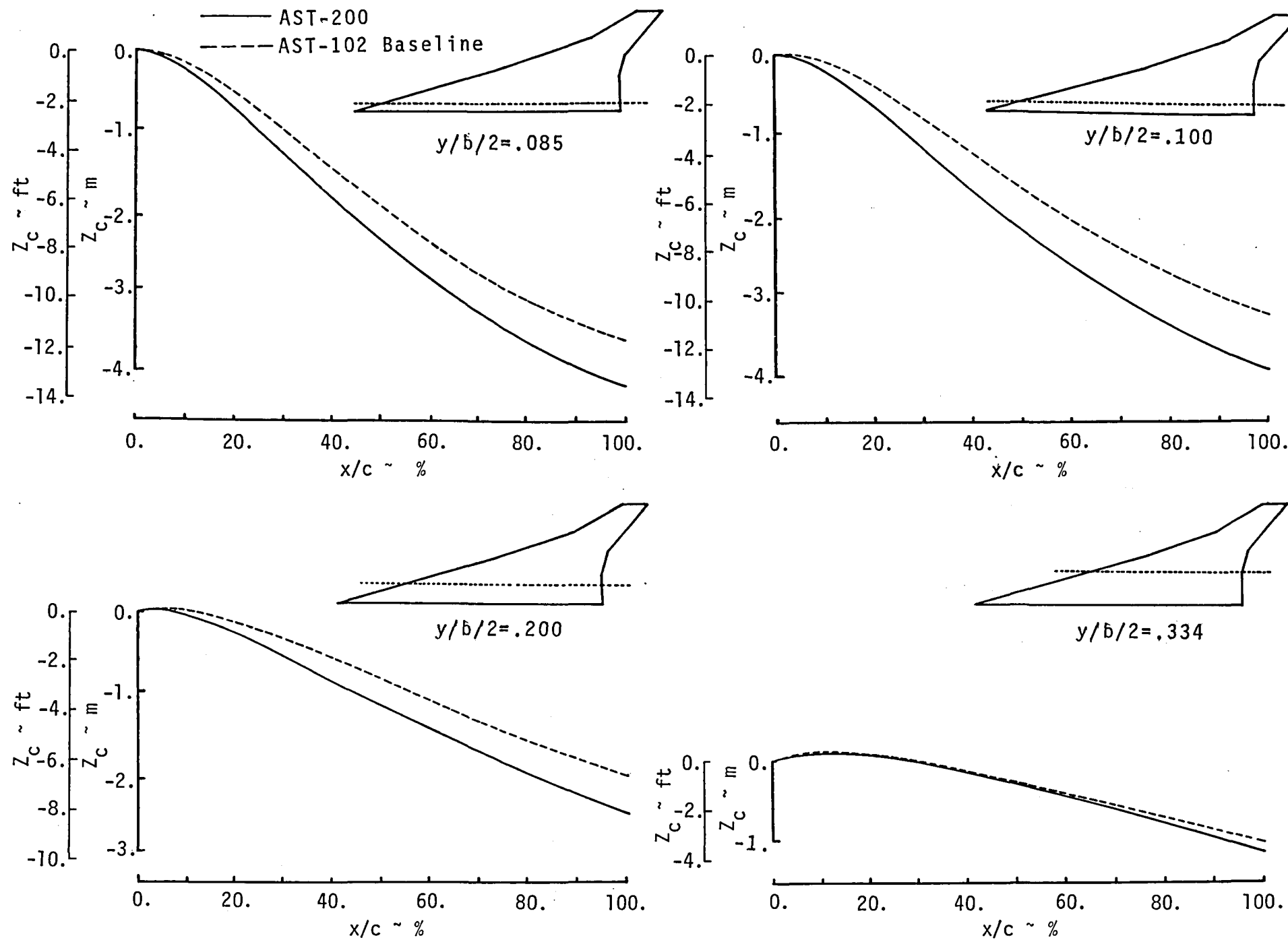
(a) Inboard sections.

Figure 6. - Comparison of AST-102 baseline and AST-200 wing
camber distributions.
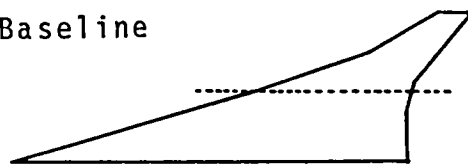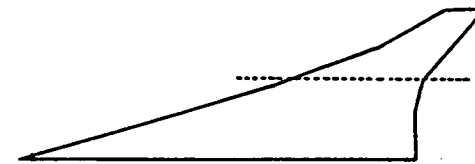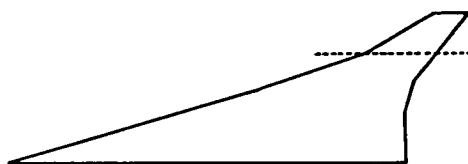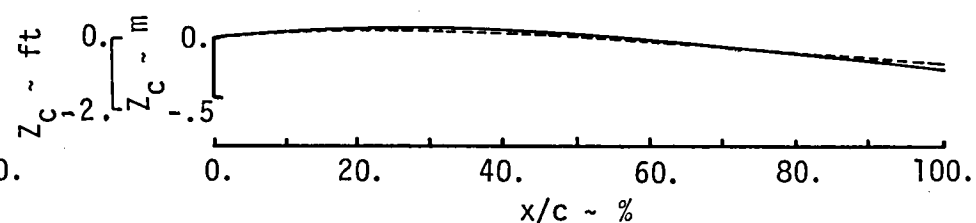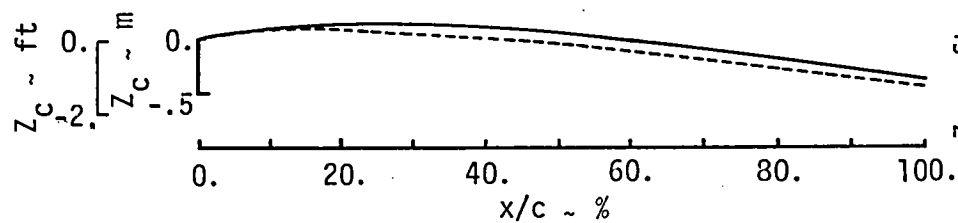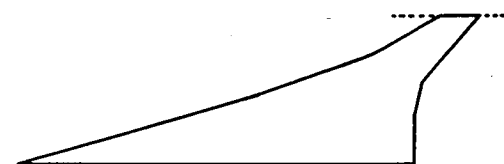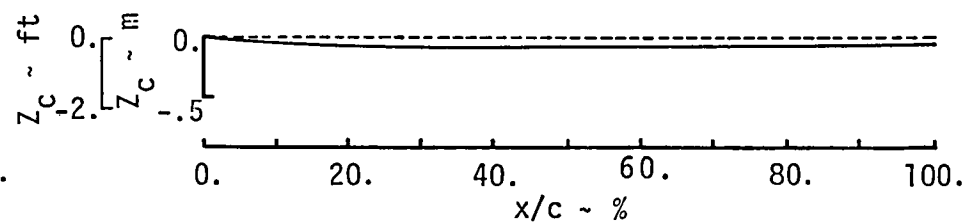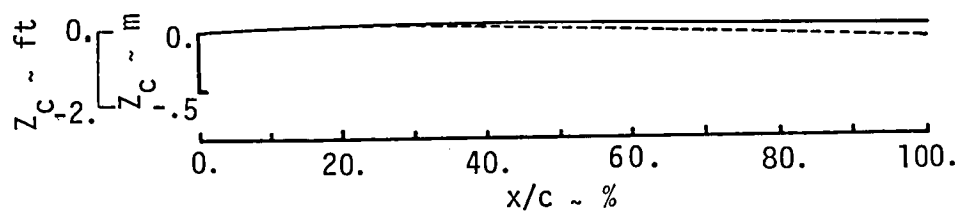
(b) Outboard sections.

Figure 6. - Concluded.
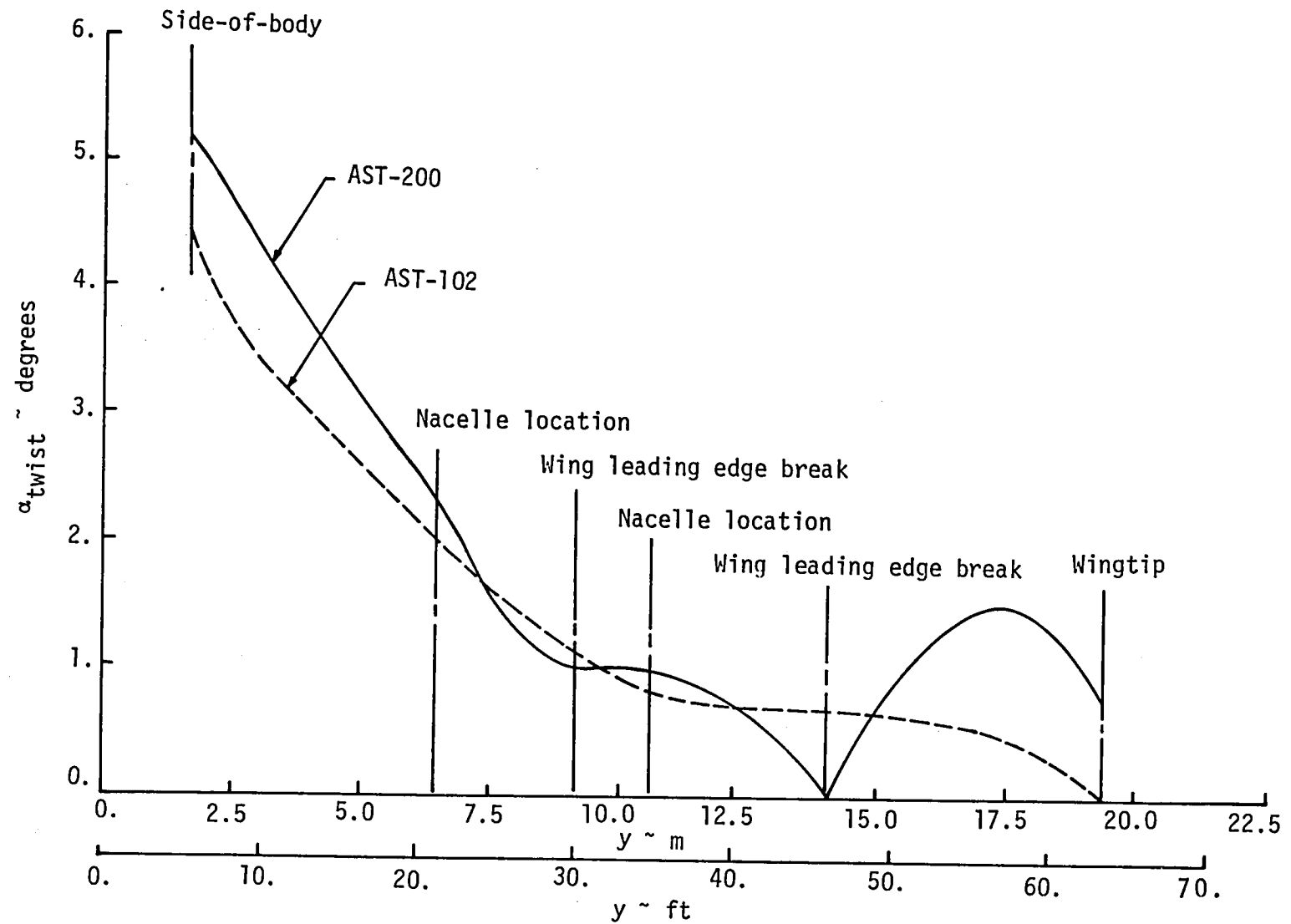
Figure 7. - Comparison of AST-102 baseline and AST-200 wing twist distributions.

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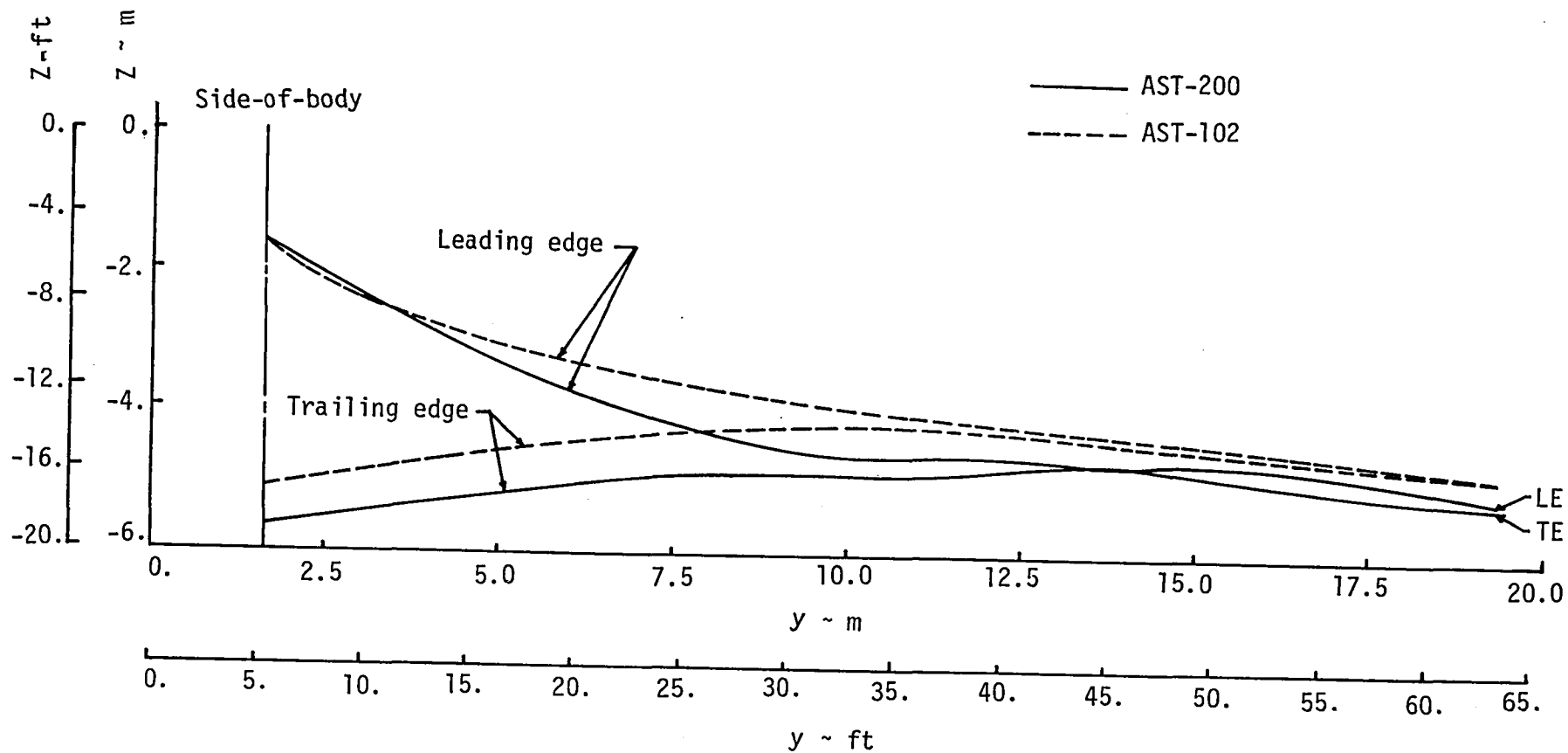
Figure 8. Wing shear distribution comparison.
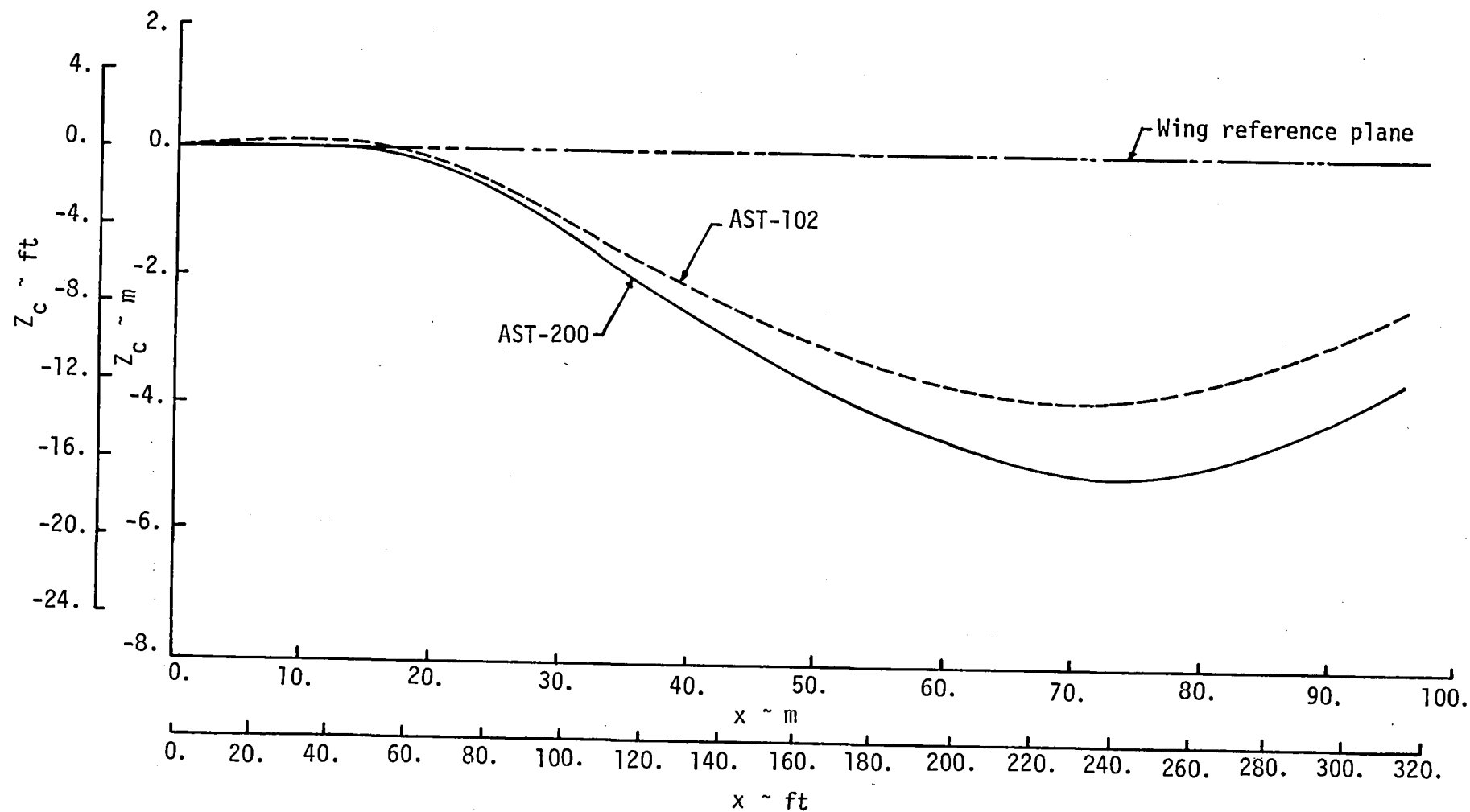
Figure 9. - Fuselage camber comparison.
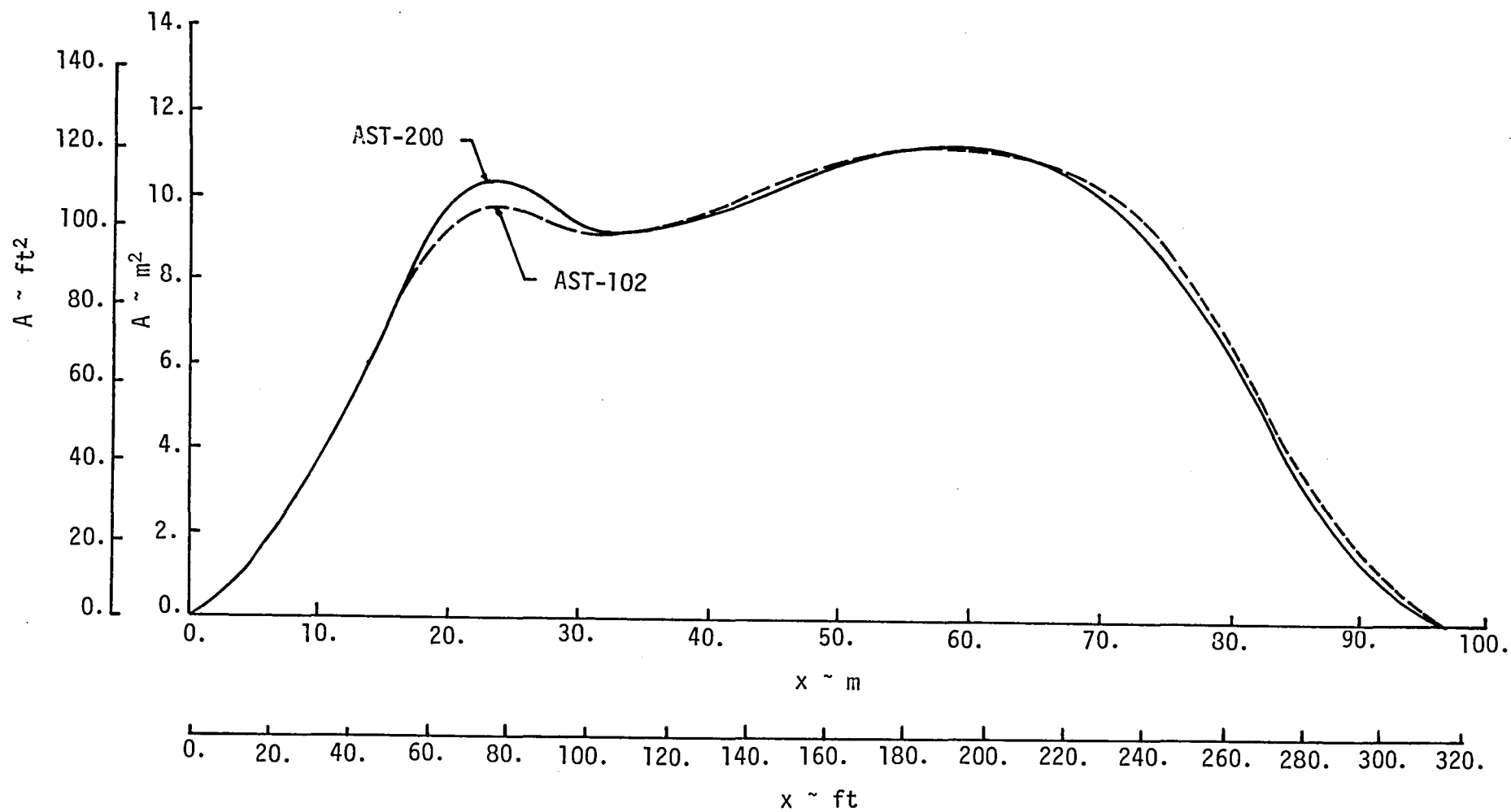
Figure 10. - Fuselage area distribution comparison.
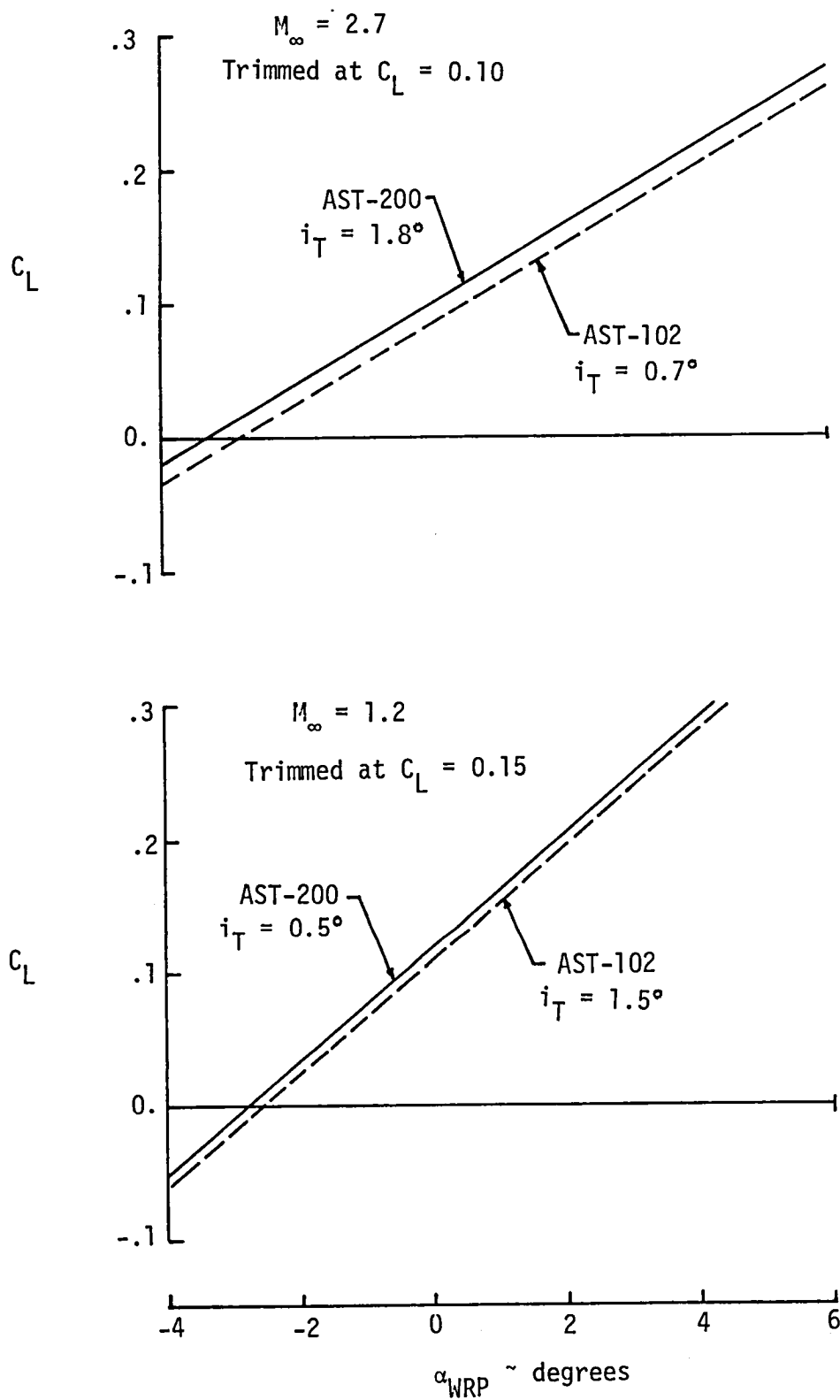
(a) Lift comparison.

Figure 11. - Aerodynamic performance.
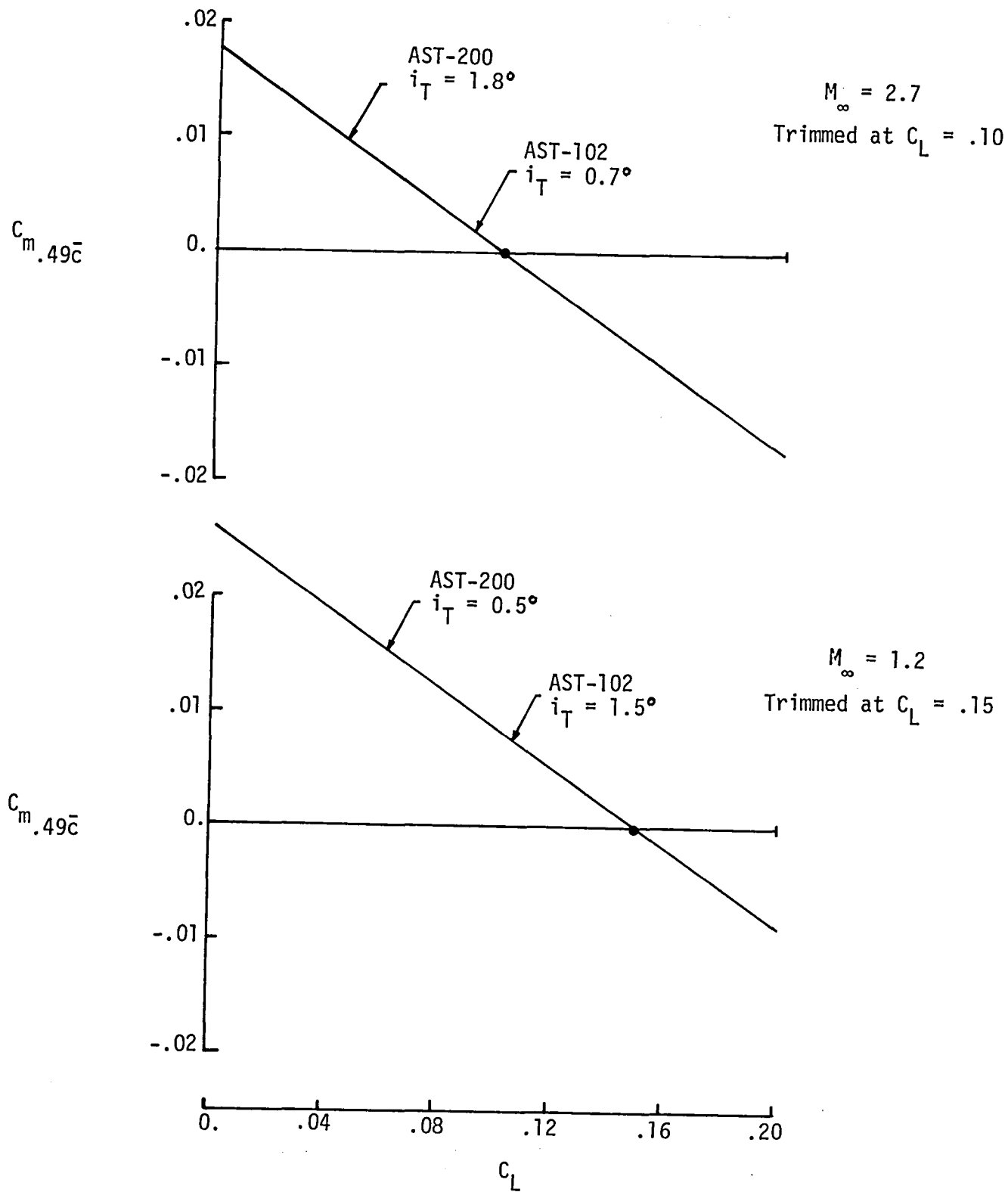
(b) Pitching moment comparison.

Figure 11. - Continued.
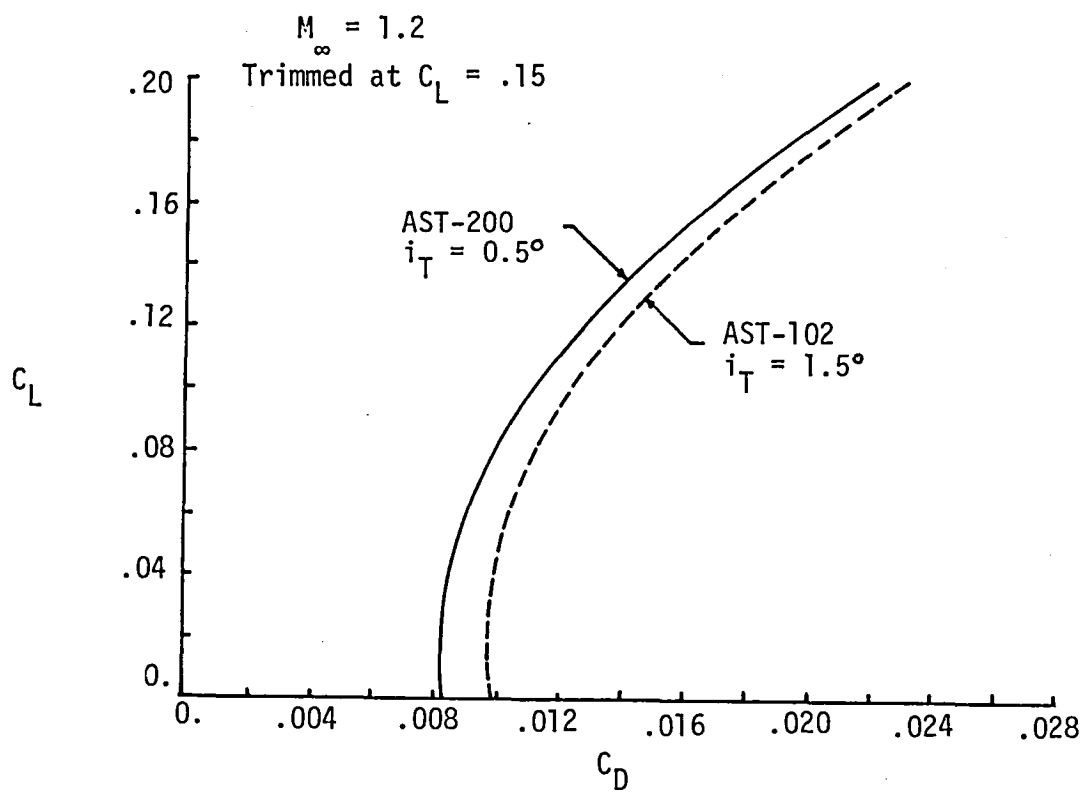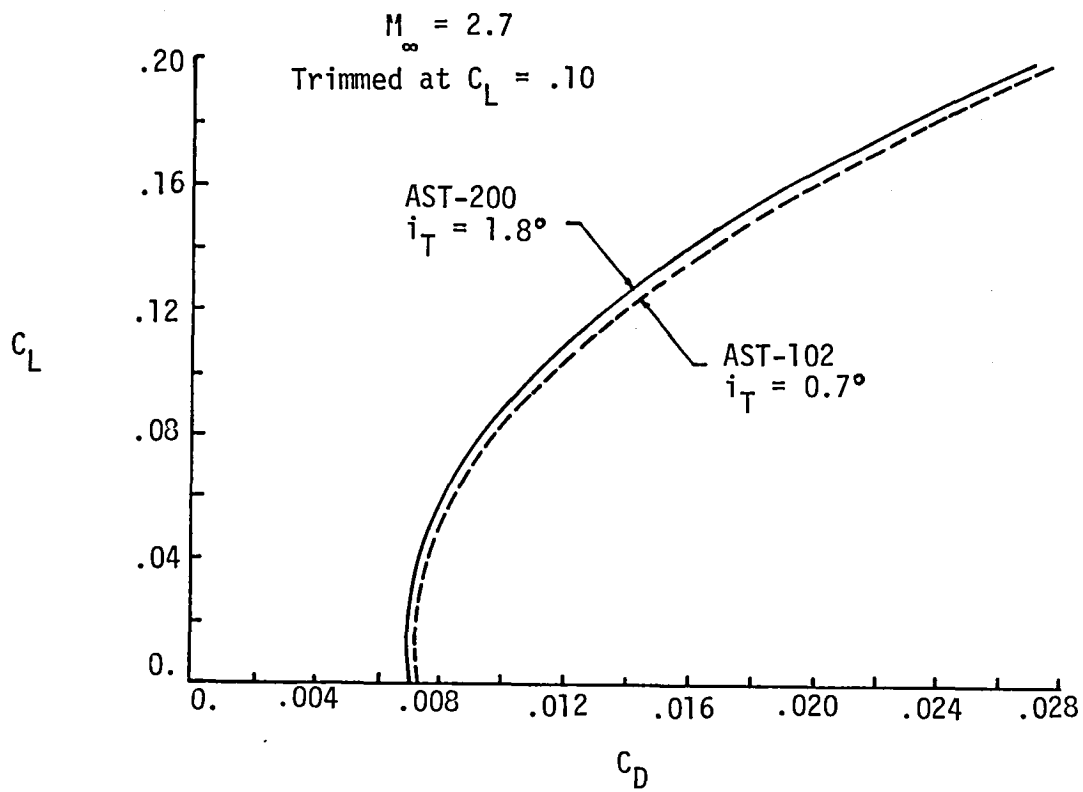
(c) Drag comparison.

Figure 11. - Continued.
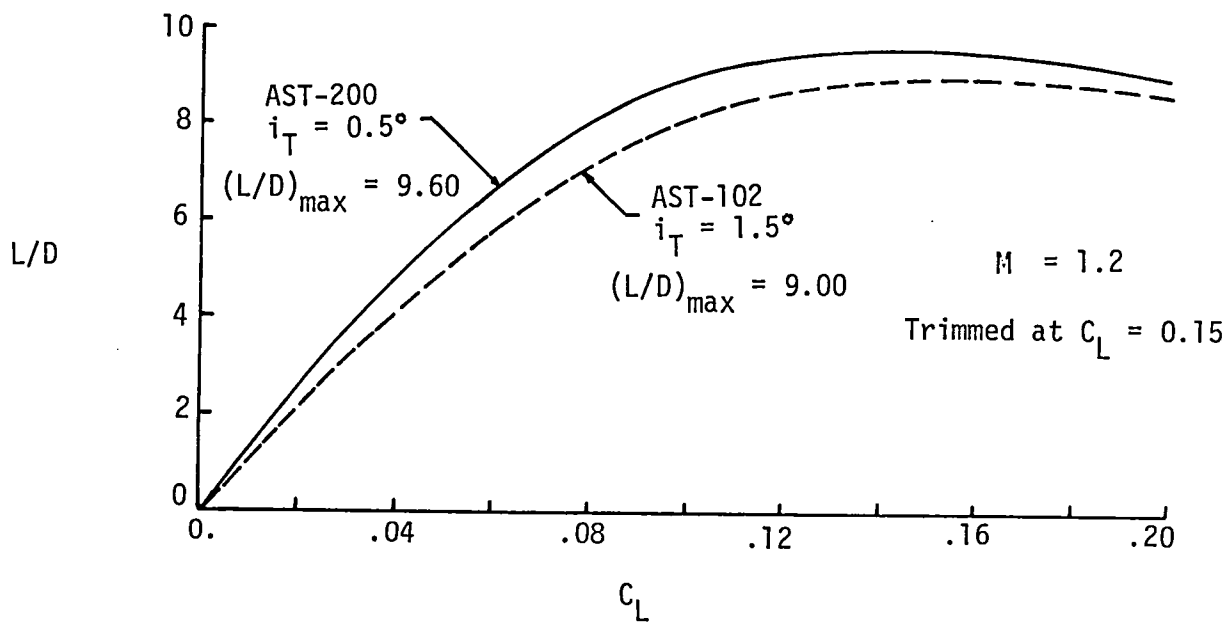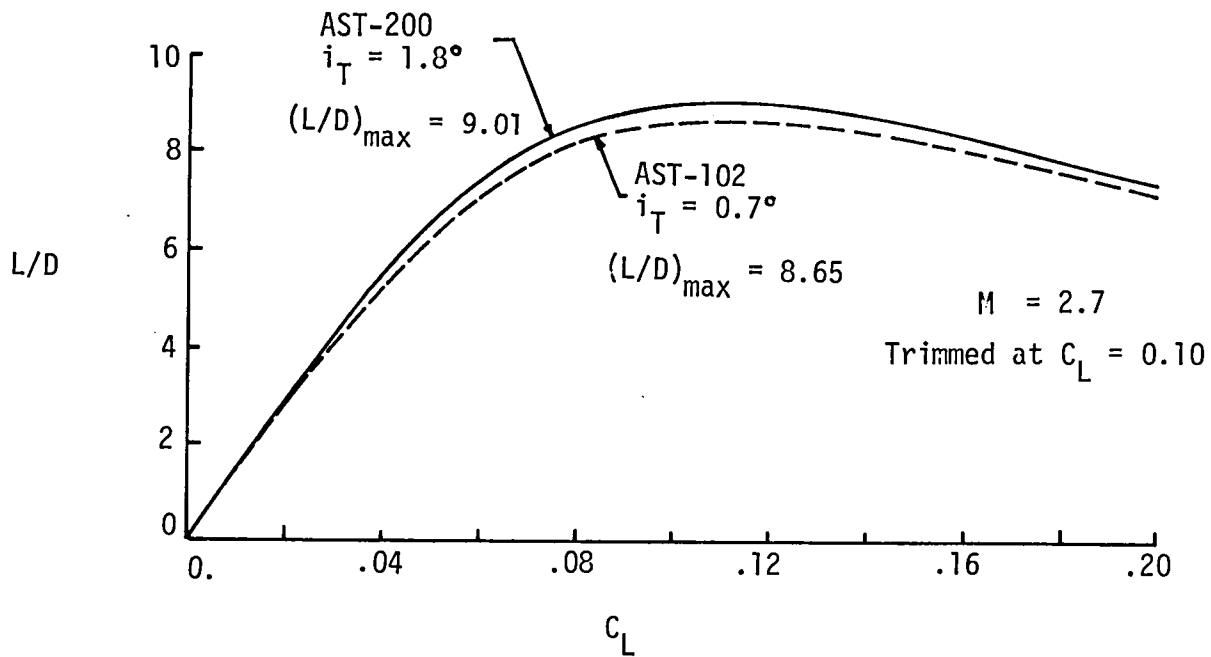
(d) L/D comparison.

Figure 11. - Concluded.

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15. Supplementary Notes

Technical Monitor - Samuel M. Dollyhigh

16. Abstract

The design and analysis of a supersonic transport configuration has been conducted using linear theory methods in conjunction with appropriate constraints. A configuration which was developed through previous systems studies has been used as the baseline for the present design and analysis. Wing optimization centered on the determination of the required twist and camber and proper integration of the wing and fuselage. Also included in the design are aerodynamic refinements to the baseline wing thickness distribution and nacelle shape. Analysis to the baseline and revised configurations indicated an improvement in lift-to-drag ratio of 0.36 at the Mach 2.7 cruise condition. Validation of the design is planned through supersonic wing tunnel tests.

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